Vidyavardhini's
College of Engineering & Technology
Vasai Road (W)

Department of Artificial Intelligence & Data Science Engineering

Laboratory Manual

Semester	IV	**Class**	**S.E**
Course Code	CSL401		
Course Name	Analysis of Algorithms Lab		

Vidyavardhini's College of Engineering & Technology

Vision

To be a premier institution of technical education; always aiming at becoming a valuable resource for industry and society.

Mission

- To provide technologically inspiring environment for learning.
- To promote creativity, innovation, and professional activities.
- To inculcate ethical and moral values.
- To cater personal, professional, and societal needs through quality education.

Program Outcomes (POs):

Engineering Graduates will be able to:

- **PO1. Engineering knowledge:** Apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization to the solution of complex engineering problems.
- **PO2. Problem analysis:** Identify, formulate, review research literature, and analyze complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences.
- **PO3. Design/development of solutions:** Design solutions for complex engineering problems and design system components or processes that meet the specified needs with appropriate consideration for the public health and safety, and the cultural, societal, and environmental considerations.
- **PO4. Conduct investigations of complex problems:** Use research-based knowledge and research methods including design of experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions.
- **PO5. Modern tool usage:** Create, select, and apply appropriate techniques, resources, and modern engineering and IT tools including prediction and modeling to complex engineering activities with an understanding of the limitations.
- **PO6. The engineer and society:** Apply reasoning informed by the contextual knowledge to assess societal, health, safety, legal and cultural issues and the consequent responsibilities relevant to the professional engineering practice.
- **PO7. Environment and sustainability:** Understand the impact of the professional engineering solutions in societal and environmental contexts, and demonstrate the knowledge of, and need for sustainable development.
- **PO8. Ethics:** Apply ethical principles and commit to professional ethics and responsibilities and norms of the engineering practice.
- **PO9. Individual and teamwork:** Function effectively as an individual, and as a member or leader in diverse teams, and in multidisciplinary settings.
- **PO10. Communication:** Communicate effectively on complex engineering activities with the engineering community and with society at large, such as, being able to comprehend and write effective reports and design documentation, make effective presentations, and give and receive clear instructions.
- **PO11. Project management and finance:** Demonstrate knowledge and understanding of the engineering and management principles and apply these to one's own work, as a member and leader in a team, to manage projects and in multidisciplinary environments.
- **PO12. Life-long learning:** Recognize the need for and have the preparation and ability to engage in independent and life-long learning in the broadest context of technological change.

Course Objective

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.

Course Outcomes

At the end of the course student will be able to:		Action verbs	Bloom's Level
CSL401.1	Analyze time complexity of sorting algorithms	Analyze	Apply (Level 3)
CSL401.2	Analyze the complexity of problems solved using divide and conquer approaches	Analyze	Apply (Level 3)
CSL401.3	Implement greedy algorithms for solving Dijkstras, Minimum spanning tree & fractional knapsack.	Implement	Apply (Level 3)
CSL401.4	Implement dynamic programming algorithm for All pair shortest path and 0/1 knapsack	Apply	Apply (Level 3)
CSL401.5	Implement backtracking and branch and bound for 15 puzzle, N queen and sum of subset problem	Apply	Apply (Level 3)
CSL401.6	Analyze the performance of string-matching techniques	Analyze	Apply (Level 3)

Mapping of Experiments with Course Outcomes

Sr. No	Title	CSL 401.1	CSL401.2	CSL 401.3	CSL 401.4	CSL 401.5	CSL 401.6
1.	To implement Insertion Sort and Comparative analysis for large values of 'n'.	3	-	-	-	-	-
2.	To implement Selection Sort and Comparative analysis for large values of 'n'	3	-	-	-	-	-
3.	To implement Quick Sort and Comparative analysis for large values of 'n' using DAC technique.	-	3	-	-	-	-
4.	To implement Binary Search for 'n' number and perform analysis using DAC technique.	-	3	-	-	-	-
5.	To implement Fractional Knap Sack using Greedy Method.	-	-	3	-	-	-
6.	To implement Prim's MST Algorithm using Greedy Method.	-	-	3	-	-	-
7.	To implement Kruskal's MST Algorithm using Greedy Method.	-	-	3	-	-	-
8.	To implement Single Source Shortest Path Algorithm using Dynamic (Bellman Ford) Method.	-	-	-	3	-	-
9.	To implement Travelling Salesperson Problem using Dynamic Approach.	-	-	-	3	-	-
10.	To implement Sub of Subset problem using Backtracking method.	-	-	-	-	3	-
11.	To implement 15 puzzle problem using Branch and Bound Method.	-	-	-	-	3	-
12.	Implement the Naïve string-matching algorithm and analyse its complexity.	-	-	-	-	-	3

Enter correlation level 1, 2 or 3 as defined below
1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High)

If there is no correlation put "— ".

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12.	Implement the Naïve string-matching algorithm and analyse its complexity.				

D.O.P: Date of performance

D.O.C : Date of correction

Experiment No.1
Insertion Sort
Date of Performance:
Date of Submission:

Title: Insertion Sort

Aim: To implement Selection Comparative analysis for large values of 'n'

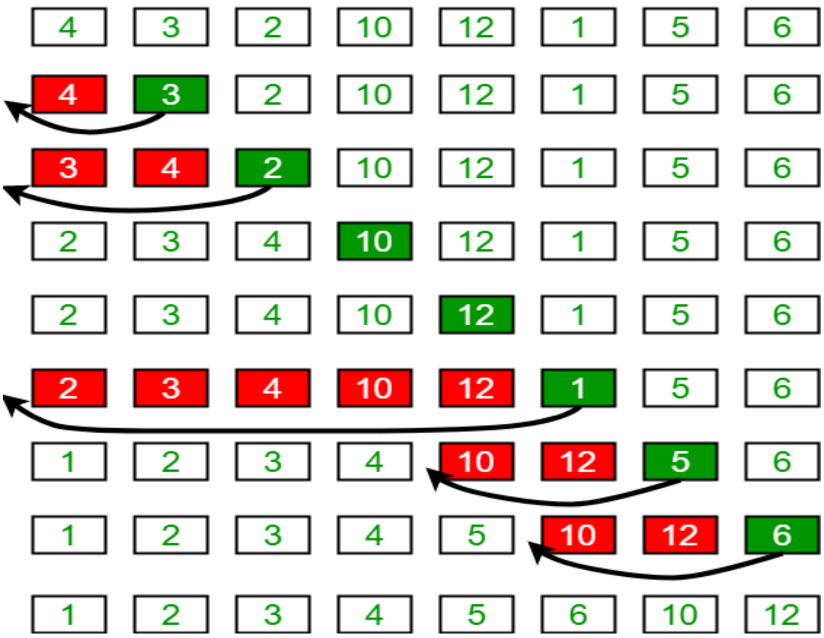
Objective: To introduce the methods of designing and analysing algorithms

Theory:

Insertion sort is a simple sorting algorithm that works similar to the way you sort playing cards in your hands. The array is virtually split into a sorted and an unsorted part. Values from the unsorted part are picked and placed at the correct position in the sorted part.

Example:

Insertion Sort Execution Example



Algorithm and Complexity:

INSERTION-SORT(A)	*cost*	*times*
for $j = 2$ **to** $A.length$	c_1	n
$key = A[j]$	c_2	$n-1$
// Insert $A[j]$ into the sorted sequence $A[1 \,..\, j-1]$.	0	$n-1$
$i = j-1$	c_4	$n-1$
while $i > 0$ and $A[i] > key$	c_5	$\sum_{j=2}^{n} t_j$
$A[i+1] = A[i]$	c_6	$\sum_{j=2}^{n} (t_j - 1)$
$i = i-1$	c_7	$\sum_{j=2}^{n} (t_j - 1)$
$A[i+1] = key$	c_8	$n-1$

Implementation:

```
#include <stdio.h>


void insertionSort(int arr[], int n) {
  int i, key, j;
  for (i = 1; i < n; i++) {
    key = arr[i];
    j = i - 1;

    /* Move elements of arr[0..i-1], that are greater than key,
      to one position ahead of their current position */
    while (j >= 0 && arr[j] > key) {
      arr[j + 1] = arr[j];
```

```
            j = j - 1;
        }
        arr[j + 1] = key;
    }
}

int main() {
    int arr[] = {64, 25, 12, 22, 11};
    int n = sizeof(arr) / sizeof(arr[0]);
    printf("Array before sorting:\n");
    for (int i = 0; i < n; i++) {
        printf("%d ", arr[i]);
    }
    printf("\n");

    insertionSort(arr, n);

    printf("Array after sorting:\n");
    for (int i = 0; i < n; i++) {
        printf("%d ", arr[i]);
    }
    printf("\n");
```

```
    return 0;
}
```

Conclusion: Merge Sort algorithm has been successfully implemented.

Experiment No.2
Selection Sort
Date of Performance:
Date of Submission:

Experiment No. 2

Title: Selection Sort

Aim: To implement Selection Comparative analysis for large values of 'n'

Objective: To introduce the methods of designing and analyzing algorithms

Theory:

Selection sort is a sorting algorithm, specifically an in-place comparison sort. Selection sort is noted for its simplicity, and it has performance advantages over more complicated algorithms in certain situations, particularly where auxiliary memory is limited.

The algorithm divides the input list into two parts: the sub list of items already sorted, which is built up from left to right at the front (left) of the list, and the sub list of items remaining to be sorted that occupy the rest of the list. Initially, the sorted sub list is empty and the unsorted sub list is the entire input list. The algorithm proceeds by finding the smallest (or largest, depending on sorting order) element in the unsorted sub list, exchanging it with the leftmost unsorted element (putting it in sorted order), and moving the sublist boundaries one element to the right.

Example:

arr[] = 64 25 12 22 11

// Find the minimum element in arr[0...4] // and place it at beginning

11 25 12 22 64

// Find the minimum element in arr[1...4] // and place it at beginning of arr[1...4]

11 12 25 22 64

// Find the minimum element in arr[2...4] // and place it at beginning of arr[2...4]

11 12 **22** 25 64

// Find the minimum element in arr[3...4] // and place it at beginning of arr[3...4]

11 12 22 **25** 64

Algorithm and Complexity:

Alg.: SELECTION-SORT(A)		
	cost	Times
n ← length[A]	c_1	1
for j ← 1 to n - 1	c_2	n-1
do smallest ← j	c_3	n-1
for i ← j + 1 to n	c_4	$\sum_{j=1}^{n-1}(n-j+1)$
≈ n2/2 comparisons, do if A[i]<A[smallest]	c_5	$\sum_{j=1}^{n-1}(n-j)$
then smallest ← i	c_6	$\sum_{j=1}^{n-1}(n-j)$
≈ n exchanges, exchange A[j] ↔ A[smallest]	c_7	n-1

Implementation:

```
#include <stdio.h>


void selectionSort(int arr[], int n) {
    int i, j, minIndex, temp;
    for (i = 0; i < n - 1; i++) {
        minIndex = i;
        for (j = i + 1; j < n; j++) {
            if (arr[j] < arr[minIndex]) {
                minIndex = j;
            }
        }
        // Swap arr[i] and arr[minIndex]
        temp = arr[i];
        arr[i] = arr[minIndex];
        arr[minIndex] = temp;
    }
}


int main() {
    int arr[] = {64, 25, 12, 22, 11};
    int n = sizeof(arr) / sizeof(arr[0]);
    printf("Array before sorting:\n");
```

```
    for (int i = 0; i < n; i++) {
        printf("%d ", arr[i]);
    }
    printf("\n");

    selectionSort(arr, n);

    printf("Array after sorting:\n");
    for (int i = 0; i < n; i++) {
        printf("%d ", arr[i]);
    }
    printf("\n");

    return 0;
}
```

Conclusion: Selection Sort algorithm has been successfully implemented.

Experiment No. 3	
Quick Sort	
Date of Performance:	
Date of Submission:	

Experiment No. 3

Title: Quick Sort

Aim: To implement Quick Sort and Comparative analysis for large values of 'n'.

Objective: To introduce the methods of designing and analyzing algorithms.

Theory:

The merge sort algorithm closely follows the divide-and-conquer paradigm. Intuitively, it operates as follows:

1. Divide: Divide the n-element sequence to be sorted into two subsequences of n=2 elements each.
2. Conquer: Sort the two subsequences recursively using merge sort.
3. Combine: Merge the two sorted subsequence to produce the sorted answer.

Partition-exchange sort or quicksort algorithm was developed in 1960 by Tony Hoare. He developed the algorithm to sort the words to be translated, to make them more easily matched to an already-sorted Russian-to-English dictionary that was stored on magnetic tape.

Quick sort algorithm on average, makes O(n log n) comparisons to sort n items. In the worst case, it makes O(n2) comparisons, though this behavior is rare. Quicksort is often faster in practice than other O(n log n) algorithms. Additionally, quicksort's sequential and localized memory references work well with a cache. Quicksort is a comparison sort and, in efficient implementations, is not a stable sort. Quicksort can be implemented with an in-place partitioning algorithm, so the entire sort can be done with only O(log n) additional space used by the stack during the recursion.

Quicksort is a divide and conquer algorithm. Quicksort first divides a large list into two smaller sub-lists: the low elements and the high elements. Quicksort can then recursively sort the sublists.

1. Elements less than pivot element.

2. Pivot element.

3. Elements greater than pivot element.

Where pivot as middle element of large list. Let's understand through example:

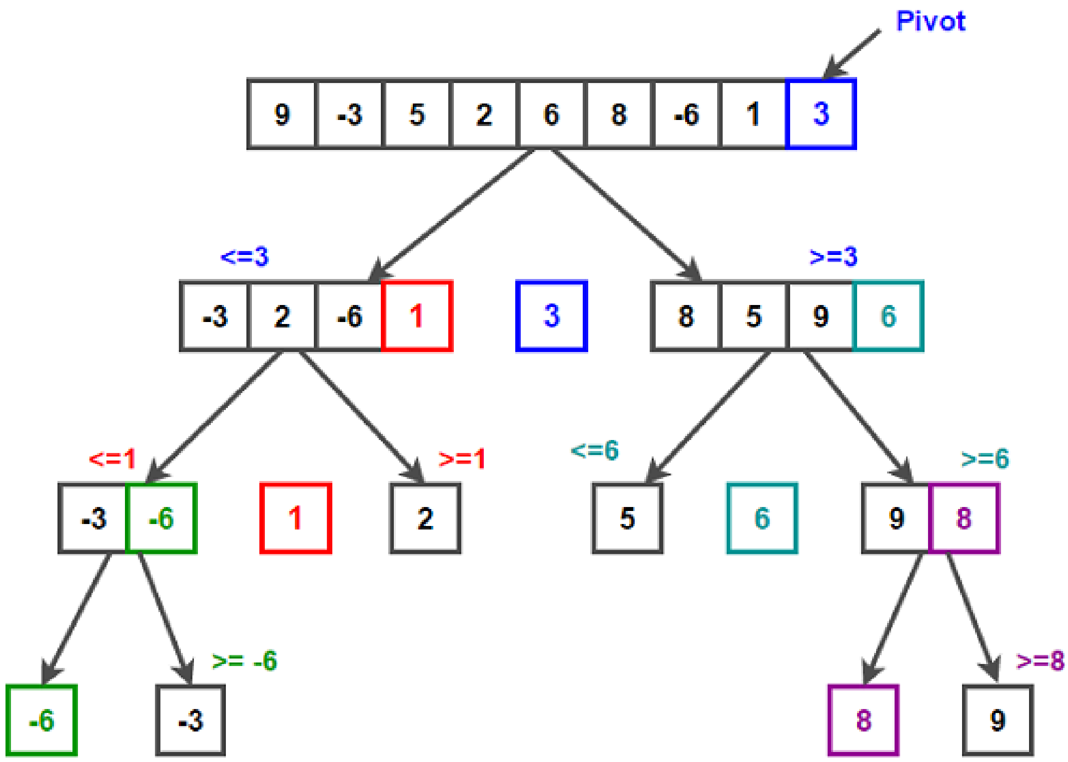
List : 3 7 8 5 2 1 9 5 4

In above list assume 4 is pivot element so rewrite list as:

3 1 2 4 5 8 9 5 7

Here, I want to say that we set the pivot element (4) which has in left side elements are less than and right hand side elements are greater than. Now you think, how's arrange the less than and greater than elements? Be patient, you get answer soon.

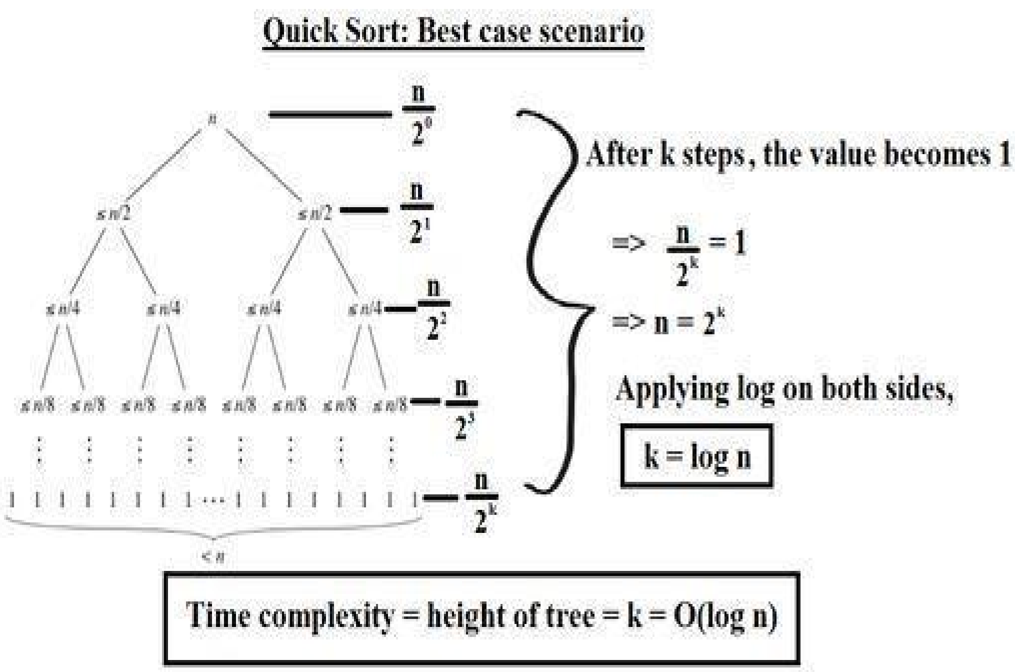
Example:

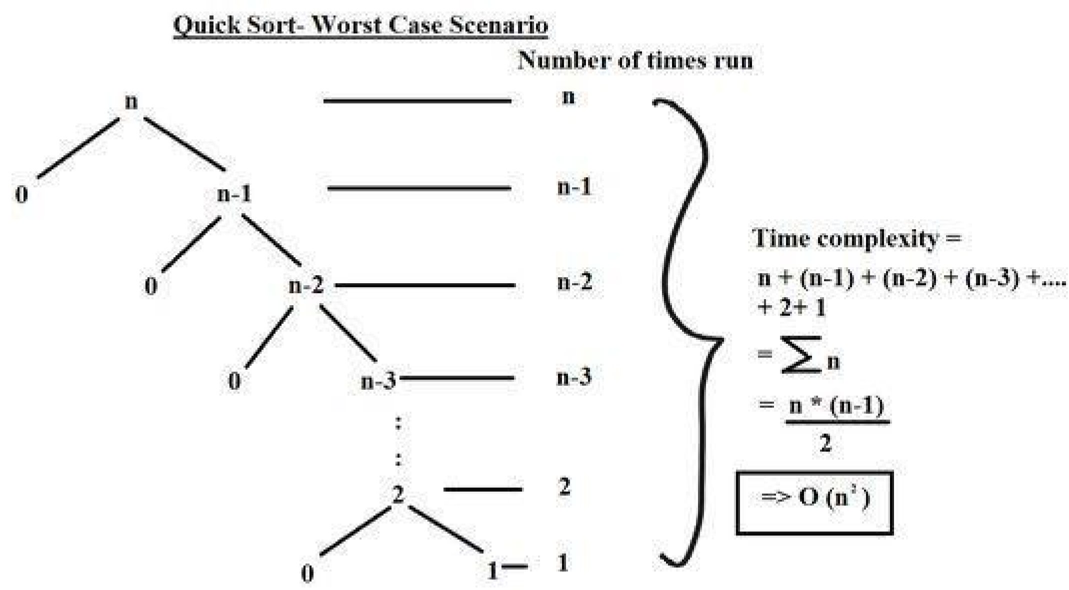



```
/* low  --> Starting index,  high  --> Ending index */
quickSort(arr[], low, high)
{
    if (low < high)
    {
        /* pi is partitioning index, arr[pi] is now
           at right place */
        pi = partition(arr, low, high);
        quickSort(arr, low, pi - 1);  // Before pi
        quickSort(arr, pi + 1, high); // After pi
    }
}
/* This function takes last element as pivot, places
   the pivot element at its correct position in sorted
    array, and places all smaller (smaller than pivot)
   to left of pivot and all greater elements to right
   of pivot */
```

```
partition (arr[], low, high)
{
   // pivot (Element to be placed at right position)
   pivot = arr[high];

   i = (low - 1)  // Index of smaller element and indicates the
                  // right position of pivot found so far
   for (j = low; j <= high- 1; j++)
   {
      // If current element is smaller than the pivot
      if (arr[j] < pivot)
      {
         i++;    // increment index of smaller element
         swap arr[i] and arr[j]
      }
   }
   swap arr[i + 1] and arr[high])
   return (i + 1)
}
```





Implementation:

```
#include <stdio.h>


// Function to partition the array and return the pivot index

int partition(int arr[], int low, int high) {

    int pivot = arr[high];

    int i = low - 1;


    for (int j = low; j < high; j++) {

        if (arr[j] <= pivot) {

            i++;

            // Swap arr[i] and arr[j]

            int temp = arr[i];

            arr[i] = arr[j];
```

```
            arr[j] = temp;
        }
    }

    // Swap arr[i+1] and arr[high] (pivot)
    int temp = arr[i + 1];
    arr[i + 1] = arr[high];
    arr[high] = temp;

    return i + 1;
}

// Function to perform QuickSort on the array
void quickSort(int arr[], int low, int high) {
    if (low < high) {
        // Partition the array and get the pivot index
        int pivotIndex = partition(arr, low, high);

        // Recursively sort the subarrays
        quickSort(arr, low, pivotIndex - 1);
        quickSort(arr, pivotIndex + 1, high);
    }
}
```

```
// Function to print an array
void printArray(int arr[], int size) {
    for (int i = 0; i < size; i++) {
        printf("%d ", arr[i]);
    }
    printf("\n");
}

// Example usage
int main() {
    int arr[] = {12, 5, 7, 3, 2, 8, 4};
    int size = sizeof(arr) / sizeof(arr[0]);

    printf("Original array: ");
    printArray(arr, size);

    quickSort(arr, 0, size - 1);

    printf("Sorted array: ");
    printArray(arr, size);

    return 0;
```

}

Conclusion: Quick Sort algorithm has been successfully implemented.

Experiment No. 4
Binary Search Algorithm
Date of Performance:
Date of Submission:

Experiment No. 4

Title: Binary Search Algorithm

Aim: To study and implement Binary Search Algorithm

Objective: To introduce Divide and Conquer based algorithms

Theory:

Search a sorted array by repeatedly dividing the search interval in half. Begin with an interval covering the whole array. If the value of the search key is less than the item in the middle of the interval, narrow the interval to the lower half. Otherwise, narrow it to the upper half. Repeatedly check until the value is found or the interval is empty

- Binary search is efficient than linear search. For binary search, the array must be sorted, which is not required in case of linear search.
- It is divide and conquer based search technique.
- In each step the algorithms divides the list into two halves and check if the element to be searched is on upper or lower half the array
- If the element is found, algorithm returns.

The idea of binary search is to use the information that the array is sorted and reduce the time complexity to O(Log n).

- Compare x with the middle element.
- If x matches with the middle element, we return the mid index.
- Else If x is greater than the mid element, then x can only lie in the right half subarray after the mid element. So we recur for the right half.
- Else (x is smaller) recur for the left half.
- Binary Search reduces search space by half in every iterations. In a linear search, search space was reduced by one only.
- n=elements in the array
- Binary Search would hit the bottom very quickly.

	Linear Search	Binary Search
2nd iteration	n-1	n/2
3rd iteration	n-2	n/4

Example:

Algorithm BINARY_SEARCH(A, key)

// Description: Perform BS on array A

// I/P : array A of size n & key element to be searched.

// O/P : Success/failure.

low ← 1
high ← n
while low < high do
  mid ← (low+high)/2
  if A[mid] == key then
    return mid
  else if A[mid] < key then
    low ← mid+1
  else high ← mid-1
  end
end
return 0

A {11, 22, 33, 44, 55, 66, 77, 88}
(indices 1 2 3 4 5 6 7 8)

key = 33

low = 1
high = 8
mid = 1+8/2
= 4
A[4] == 33 ×
A[4] < 33 ×
44
high = 4-1
high = 3

{11, 22, 33}
1 2 3

low = 1
high = 3
mid = 1+3/2
= 2
A[2] == 33 ×
22 < 33
low = 3

{33} mid = 3+3/2 = 3
A[3] = 33
A[mid] = 33
key = A[3]

Algorithm and Complexity:

The binary search

- Algorithm 3: the binary search algorithm

Procedure binary search (x: integer, a_1, a_2, …,a_n: increasing integers)
  i :=1 { i is left endpoint of search interval}
  j :=n { j is right endpoint of search interval}
While i < j
begin
  m := $\lfloor(i + j) / 2\rfloor$
  if x > a_m **then** i := m+1
  else j := m
end
If x = a_i **then** *location* := i
else *location* :=0
{*location* is the subscript of the term equal to x, or 0 if x is not found}

2

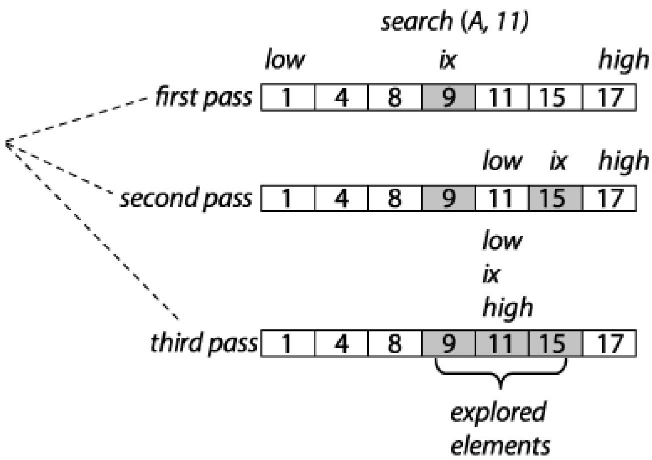
BINARY SEARCH

Best	Average	Worst
O (1)	O (log n)	O (log n)

Array

Divide and Conquer

```
search (A, t)
  low = 0
  high = n −1
  while (low ≤ high) do
    ix = (low + high)/2
    if (t = A[ix]) then
      return true
    else if (t < A[ix]) then
      high = ix − 1
    else low = ix + 1
  return false
end
```



Best Case:
Key is first compared with the middle element of the array.
The key is in the middle position of the array, the algorithm does only one comparison, irrespective of the size of the array.
T(n)=1

Worst Case:
In each iteration search space of BS is reduced by half, Maximum log n(base 2) array divisions are possible.
Recurrence relation is
T(n)=T(n/2) +1
Running Time is O(logn).

Average Case:

Key element neither is in the middle nor at the leaf level of the search tree.
It does half of the log n(base 2).
Base case=O(1)
Average and worst case=O(logn)

Implementation:

```
#include <stdio.h>



// Function to perform binary search

int binarySearch(int arr[], int left, int right, int target) {

    while (left <= right) {

        int mid = left + (right - left) / 2;



        // Check if target is present at mid

        if (arr[mid] == target)

            return mid;
```

```
        // If target is greater, ignore left half
        if (arr[mid] < target)
            left = mid + 1;

        // If target is smaller, ignore right half
        else
            right = mid - 1;
    }

    // If target is not found, return -1
    return -1;
}

// Driver program to test above function
int main() {
    int arr[] = {2, 3, 4, 10, 40};
    int target = 10;
    int arr_size = sizeof(arr) / sizeof(arr[0]);

    int result = binarySearch(arr, 0, arr_size - 1, target);

    if (result != -1)
```

```
        printf("Element is present at index %d\n", result);
    else
        printf("Element is not present in array\n");

    return 0;
}
```

Conclusion: Binary Search algorithm has been successfully implemented.

Experiment No. 5
Fractional Knapsack using Greedy Method
Date of Performance:
Date of Submission:

Experiment No. 5

Title: Fraction Knapsack

Aim: To study and implement Fraction Knapsack Algorithm

Objective: To introduce Greedy based algorithms

Theory:

Greedy method or technique is used to solve Optimization problems. A solution that can be maximized or minimized is called Optimal Solution.

The knapsack problem or rucksack problem is a problem in combinatorial optimization: Given a set of items, each with a mass and a value, determine the number of each item to include in a collection so that the total weight is less than or equal to a given limit and the total value is as large as possible. It derives its name from the problem faced by someone who is constrained by a fixed size knapsack and must fill it with the most valuable items. The most common problem being solved is the 0-1 knapsack problem, which restricts the number xi of copies of each kind of item to zero or one.

In Knapsack problem we are given:1) n objects 2) Knapsack with capacity m, 3) An object i is associated with profit Wi , 4) An object i is associated with profit Pi , 5) when an object i is placed in knapsack we get profit Pi Xi .

Here objects can be broken into pieces (Xi Values) The Objective of Knapsack problem is to maximize the profit.

Example:

In this version of Knapsack problem, items can be broken into smaller pieces. So, the thief may take only a fraction x_i of i^{th} item.

$$0 \leqslant xi \leqslant 1$$

The i^{th} item contributes the weight xi.wi to the total weight in the knapsack and profit xi.pi to the total profit**.**

greedy_fractional_knapsack (w[1..n], p[1..n], W)

```
for i=1 to n
   do x[i] = 0
weight = 0
for i=1 to n
   if weight + w[i] ≤ W then
      x[i] = 1
      weight = weight + w[i]
   else
      x[i] = (W-weight) / w[i]
      weight = W
      break
return x
```

i=1 → B
0+10 ≤ 60
x[i] = 1
wt = 10

i=2 → A
10+40
50 ≤ 60
x[i] = 2
10+40
wt = 50

i=3 → C
(60-50)/20
x[i] = 1/2   10/20 = 1/2
wt = 60

x = [A, B, 1/2 C]

Total wt
10+40+20*(10/20)
= 60

~~x[i] = 0~~
~~wt = 0~~

Total profit is
100+280+120*(10/20)
380+60 = 440

Ex: W = 60

Item	A	B	C	D
profit	280	100	120	120
weight	40	10	20	24
Ratio $\left(\frac{p_i}{w_i}\right)$	7	10	6	5

provided items are not sorted based on $\frac{p_i}{w_i}$.

sorted

Item	B	A	C	D
profit	100	280	120	120
weight	10	40	20	24
Ratio $\left(\frac{p_i}{w_i}\right)$	10	7	6	5

Algorithm:

Hence, the objective of this algorithm is to

$$maximize \sum_{n=1}^{n}(x_i . pi)$$

subject to constraint,

$$\sum_{n=1}^{n}(x_i . wi) \leqslant W$$

It is clear that an optimal solution must fill the knapsack exactly, otherwise we could add a fraction of one of the remaining items and increase the overall profit.

Thus, an optimal solution can be obtained by

$$\boxed{\sum_{n=1}^{n}(x_i . wi) = W}$$

In this context, first we need to sort those items according to the value of $\frac{p_i}{w_i}$, so that $\frac{p_i+1}{w_i+1}$ ≤ $\frac{p_i}{w_i}$. Here, ***x*** is an array to store the fraction of items.

```
Algorithm: Greedy-Fractional-Knapsack (w[1..n], p[1..n], W)
for i = 1 to n
   do x[i] = 0
weight = 0
for i = 1 to n
   if weight + w[i] ≤ W then
      x[i] = 1
      weight = weight + w[i]
   else
      x[i] = (W - weight) / w[i]
      weight = W
      break
return x
```

Implementation:

```
#include <stdio.h>


// Structure to represent items
struct Item {
    int value;
    int weight;
};


// Function to compare items based on their value per unit weight
int compare(const void *a, const void *b) {
    double ratio1 = (double)(((struct Item*)a)->value) / (((struct Item*)a)->weight);
    double ratio2 = (double)(((struct Item*)b)->value) / (((struct Item*)b)->weight);
```

```
    if (ratio1 < ratio2)
        return 1;
    else if (ratio1 > ratio2)
        return -1;
    else
        return 0;
}

// Function to solve fractional knapsack problem
void fractionalKnapsack(struct Item arr[], int n, int capacity) {
    // Sort items based on value per unit weight
    qsort(arr, n, sizeof(arr[0]), compare);

    int currentWeight = 0; // Current weight in knapsack
    double finalValue = 0.0; // Final value of items selected

    for (int i = 0; i < n; i++) {
        // If adding the current item won't overflow the knapsack
        if (currentWeight + arr[i].weight <= capacity) {
            currentWeight += arr[i].weight;
            finalValue += arr[i].value;
        }
        else {
```

```
        // Otherwise, add a fraction of the item to fill the knapsack
        int remainingWeight = capacity - currentWeight;
        finalValue += arr[i].value * ((double)remainingWeight / arr[i].weight);
        break; // Knapsack is full
      }
    }

    printf("Maximum value in the knapsack: %.2lf\n", finalValue);
}

int main() {
    struct Item arr[] = {{60, 10}, {100, 20}, {120, 30}};
    int n = sizeof(arr) / sizeof(arr[0]);
    int capacity = 50;
    fractionalKnapsack(arr, n, capacity);
    return 0;
}
```

Conclusion: Fractional Knapsack algorithm has been successfully implemented.

Experiment No. 6
Prim's Algorithm
Date of Performance:
Date of Submission:

Experiment No. 6

Title: Prim's Algorithm.

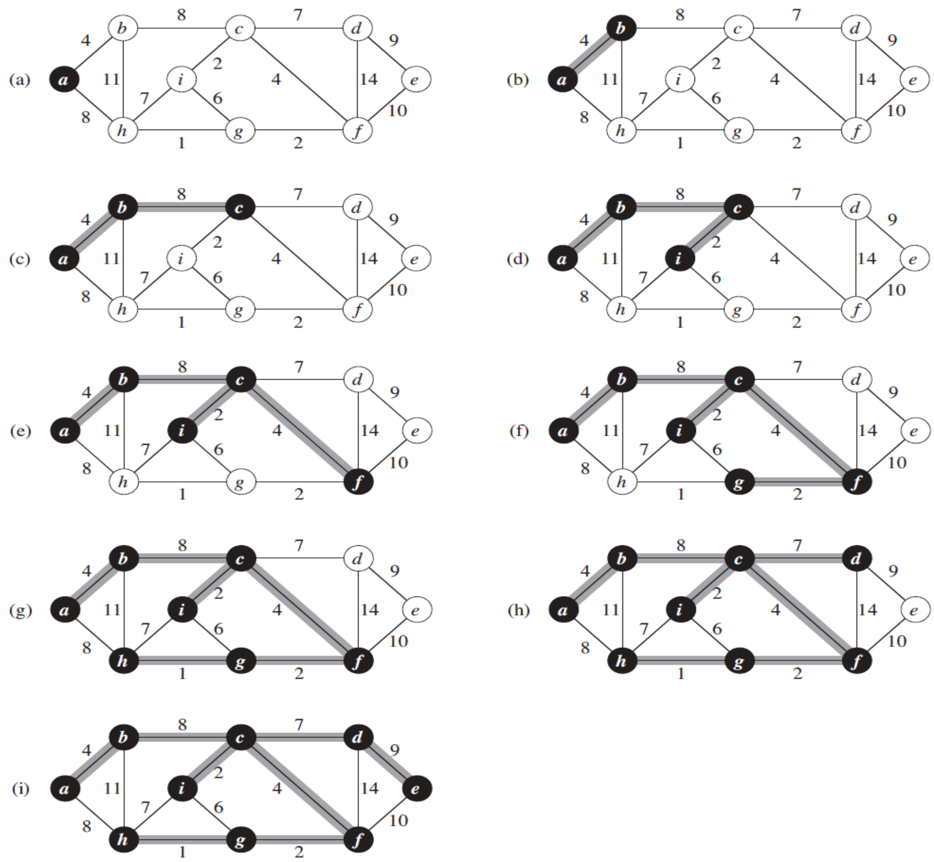
Aim: To study and implement Prim's Minimum Cost Spanning Tree Algorithm.

Objective: To introduce Greedy based algorithms

Theory:

Prim's algorithm is a greedy algorithm that finds a minimum spanning tree for a weighted undirected 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. The algorithm operates by building this tree one vertex at a time, from an arbitrary starting vertex, at each step adding the cheapest possible connection from the tree to another vertex.

Example:



Algorithm and Complexity:

```
Algorithm Prim(E, cost, n, t)
// E is the set of edges in G. cost[1 : n, 1 : n] is the cost
// adjacency matrix of an n vertex graph such that cost[i, j] is
// either a positive real number or ∞ if no edge (i, j) exists.
// A minimum spanning tree is computed and stored as a set of
// edges in the array t[1 : n − 1, 1 : 2]. (t[i, 1], t[i, 2]) is an edge in
// the minimum-cost spanning tree. The final cost is returned.
{
    Let (k, l) be an edge of minimum cost in E;
    mincost := cost[k, l];
    t[1, 1] := k; t[1, 2] := l;
    for i := 1 to n do // Initialize near.
        if (cost[i, l] < cost[i, k]) then near[i] := l;
        else near[i] := k;
    near[k] := near[l] := 0;
    for i := 2 to n − 1 do
    { // Find n − 2 additional edges for t.
        Let j be an index such that near[j] ≠ 0 and
        cost[j, near[j]] is minimum;
        t[i, 1] := j; t[i, 2] := near[j];
        mincost := mincost + cost[j, near[j]];
        near[j] := 0;
        for k := 1 to n do // Update near[ ].
            if ((near[k] ≠ 0) and (cost[k, near[k]] > cost[k, j]))
                then near[k] := j;
    }
    return mincost;
}
```

Time Complexity is O(n2), Where, n = number of vertices **Theory:**

Implemenation:

```
#include <stdio.h>

#include <stdlib.h>

#include <limits.h>



#define V 5 // Number of vertices in the graph



// Function to find the vertex with minimum key value,
```

```
// from the set of vertices not yet included in MST
int minKey(int key[], int mstSet[]) {
   int min = INT_MAX, min_index;

   for (int v = 0; v < V; v++)
      if (mstSet[v] == 0 && key[v] < min)
         min = key[v], min_index = v;

   return min_index;
}

// Function to print the constructed MST stored in parent[]
void printMST(int parent[], int graph[V][V]) {
   printf("Edge   Weight\n");
   for (int i = 1; i < V; i++)
      printf("%d - %d    %d \n", parent[i], i, graph[i][parent[i]]);
}

// Function to construct and print MST for a graph represented
// using adjacency matrix representation
void primMST(int graph[V][V]) {
   int parent[V]; // Array to store constructed MST
   int key[V];    // Key values used to pick minimum weight edge in cut
```

```
int mstSet[V]; // To represent set of vertices not yet included in MST

// Initialize all keys as INFINITE
for (int i = 0; i < V; i++)
   key[i] = INT_MAX, mstSet[i] = 0;

// Always include first vertex in MST.
// Make key 0 so that this vertex is picked as first vertex.
key[0] = 0;
parent[0] = -1; // First node is always root of MST

// The MST will have V vertices
for (int count = 0; count < V - 1; count++) {
   // Pick the minimum key vertex from the set of vertices
   // not yet included in MST
   int u = minKey(key, mstSet);

   // Add the picked vertex to the MST set
   mstSet[u] = 1;

   // Update key value and parent index of the adjacent vertices
   // of the picked vertex. Consider only those vertices which are
   // not yet included in MST
```

```
    for (int v = 0; v < V; v++)

      // graph[u][v] is non-zero only for adjacent vertices of m
      // mstSet[v] is false for vertices not yet included in MST
      // Update the key only if graph[u][v] is smaller than key[v]
      if (graph[u][v] && mstSet[v] == 0 && graph[u][v] < key[v])
        parent[v] = u, key[v] = graph[u][v];
  }

  // Print the constructed MST
  printMST(parent, graph);
}

// Driver code
int main() {
  // Graph representation using adjacency matrix
  int graph[V][V] = {
    {0, 2, 0, 6, 0},
    {2, 0, 3, 8, 5},
    {0, 3, 0, 0, 7},
    {6, 8, 0, 0, 9},
    {0, 5, 7, 9, 0}
  };
```

```
    // Print the MST
    primMST(graph);


    return 0;
}
```

Conclusion: Prim's algorithm has been successfully implemented.

Experiment No. 7
Kruskal's Algorithm
Date of Performance:
Date of Submission:

Experiment No. 7

Title: Kruskal's Algorithm.

Aim: To study and implement Kruskal's Minimum Cost Spanning Tree Algorithm.

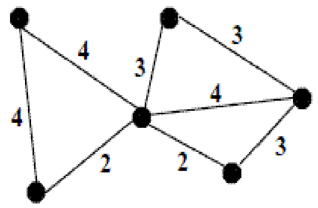
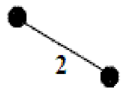
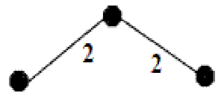
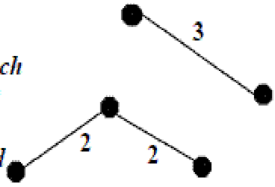
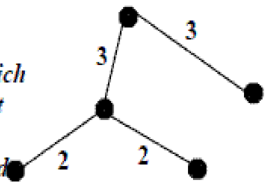
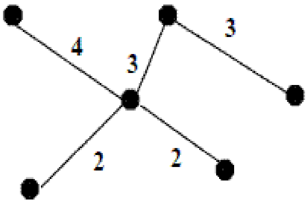
Objective: To introduce Greedy based algorithms

Theory:

Kruskal's algorithm finds a minimum spanning forest of an undirected edge-weighted graph. If the graph is connected, it finds a minimum spanning tree. (A minimum spanning tree of a connected graph is a subset of the edges that forms a tree that includes every vertex, where the sum of the weights of all the edges in the tree is minimized. For a disconnected graph, a minimum spanning forest is composed of a minimum spanning tree for each connected component.) It is a greedy algorithm in graph theory as in each step it adds the next lowest-weight edge that will not form a cycle to the minimum spanning forest.

Example:

Kruskal's Algorithm

1 *Given a network…………* 	2 *Choose the shortest edge (if there is more than one, choose any of the shortest)……..* 	3 *Choose the next shortest edge and add it……..* 
4 *Choose the next shortest edge which wouldn't create a cycle and add it.* 	5 *Choose the next shortest edge which wouldn't create a cycle and add it.* 	6 *Repeat until you have a minimal spanning tree.* 

Algorithm and Complexity:

```
Algorithm Kruskal(E, cost, n, t)
// E is the set of edges in G. G has n vertices. cost[u, v] is the
// cost of edge (u, v). t is the set of edges in the minimum-cost
// spanning tree. The final cost is returned.
{
    Construct a heap out of the edge costs using Heapify;
    for i := 1 to n do parent[i] := -1;
    // Each vertex is in a different set.
    i := 0; mincost := 0.0;
    while ((i < n - 1)  and (heap not empty)) do
    {
        Delete a minimum cost edge (u, v) from the heap
        and reheapify using Adjust;
        j := Find(u); k := Find(v);
        if (j ≠ k) then
        {
            i := i + 1;
            t[i, 1] := u; t[i, 2] := v;
            mincost := mincost + cost[u, v];
            Union(j, k);
        }
    }
    if (i ≠ n - 1) then write ("No spanning tree");
    else return mincost;
}
```

Time Complexity is O(nlog n), Where, n = number of Edges

Implemenation:

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

// Structure to represent a weighted edge in the graph
struct Edge {
   int src, dest, weight;
};

// Structure to represent a connected, undirected graph
struct Graph {
   int V, E;
   struct Edge* edge;
```

```
};

// Structure to represent a subset for union-find
struct Subset {
   int parent;
   int rank;
};

// Create a graph with V vertices and E edges
struct Graph* createGraph(int V, int E) {
   struct Graph* graph = (struct Graph*)malloc(sizeof(struct Graph));
   graph->V = V;
   graph->E = E;
   graph->edge = (struct Edge*)malloc(E * sizeof(struct Edge));
   return graph;
}

// Find set of an element i (uses path compression technique)
int find(struct Subset subsets[], int i) {
   if (subsets[i].parent != i)
      subsets[i].parent = find(subsets, subsets[i].parent);
   return subsets[i].parent;
}

// Union of two sets of x and y (uses union by rank)
void Union(struct Subset subsets[], int x, int y) {
   int xroot = find(subsets, x);
   int yroot = find(subsets, y);

   if (subsets[xroot].rank < subsets[yroot].rank)
      subsets[xroot].parent = yroot;
   else if (subsets[xroot].rank > subsets[yroot].rank)
      subsets[yroot].parent = xroot;
   else {
      subsets[yroot].parent = xroot;
      subsets[xroot].rank++;
   }
```

```
}

// Compare function for qsort
int compare(const void* a, const void* b) {
   struct Edge* aEdge = (struct Edge*)a;
   struct Edge* bEdge = (struct Edge*)b;
   return aEdge->weight - bEdge->weight;
}

// Kruskal's algorithm function
void Kruskal(struct Graph* graph) {
   int V = graph->V;
   struct Edge result[V];  // Array to store the result MST
   int e = 0;  // Index variable for result array
   int i = 0;  // Index variable for sorted edges array

   // Step 1: Sort all the edges in non-decreasing order of their weight
   qsort(graph->edge, graph->E, sizeof(graph->edge[0]), compare);

   // Allocate memory for creating V subsets
   struct Subset* subsets = (struct Subset*)malloc(V * sizeof(struct
Subset));

   // Create V subsets with single elements
   for (int v = 0; v < V; v++) {
      subsets[v].parent = v;
      subsets[v].rank = 0;
   }

   // Number of edges to be taken is equal to V-1
   while (e < V - 1 && i < graph->E) {
      // Step 2: Pick the smallest edge
      struct Edge next_edge = graph->edge[i++];

      int x = find(subsets, next_edge.src);
      int y = find(subsets, next_edge.dest);
```

```
        // If including this edge does not cause cycle, include it in result and
increment the index of result for next edge
        if (x != y) {
            result[e++] = next_edge;
            Union(subsets, x, y);
        }
    }

    // Print the edges of MST
    printf("Edges of Minimum Spanning Tree:\n");
    for (i = 0; i < e; ++i)
        printf("%d -- %d == %d\n", result[i].src, result[i].dest,
result[i].weight);

    free(subsets);
}

int main() {
    int V, E;
    printf("Enter number of vertices and edges: ");
    scanf("%d %d", &V, &E);

    struct Graph* graph = createGraph(V, E);

    printf("Enter edge details (source destination weight):\n");
    for (int i = 0; i < E; i++)
   scanf("%d %d %d", &graph->edge[i].src, &graph->edge[i].dest,
&graph->edge[i].weight);
    Kruskal(graph);

    return 0;
}
```

Conclusion: Kruskal's algorithm has been successfully implemented

Experiment No. 8
Single Source Shortest Path using Dynamic Programming (Bellman-Ford Algorithm)
Date of Performance:
Date of Submission:

Experiment No: 8

Title: Single Source Shortest Path: Bellman Ford

Aim: To study and implement Single Source Shortest Path using Dynamic Programming: Bellman Ford

Objective: To introduce Bellman Ford method

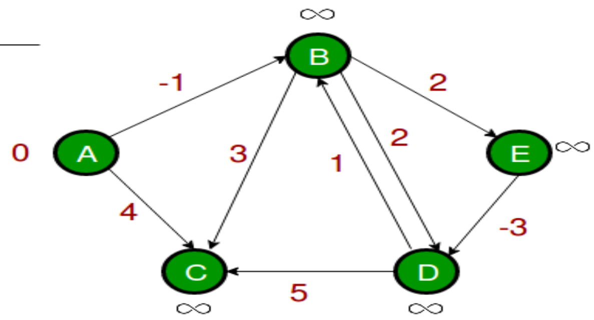
Theory:

Given a graph and a source vertex source in graph, find shortest paths from src to all vertices in the given graph. The graph may contain negative weight edges.We have discussed Dijkstra's algorithm for this problem. Dijkstra's algorithm is a Greedy algorithm and time complexity is O(VLogV) (with the use of Fibonacci heap). Dijkstra doesn't work for Graphs with negative weight edges, Bellman-Ford works for such graphs. Bellman-Ford is also simpler than Dijkstra and suites well for distributed systems. But time complexity of Bellman-Ford is O(VE), which is more than Dijkstra.

Example:

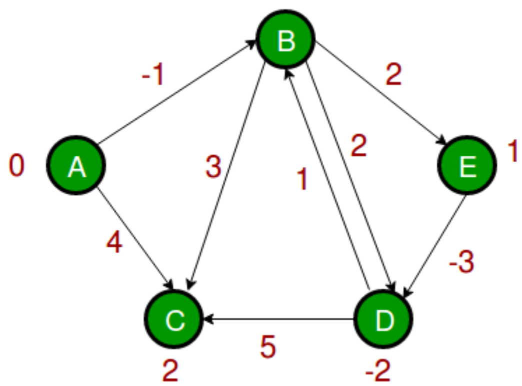
Let the given source vertex be 0. Initialize all distances as infinite, except the distance to the source itself. Total number of vertices in the graph is 5, so all edges must be processed 4 times.

A	B	C	D	E
0	∞	∞	∞	∞

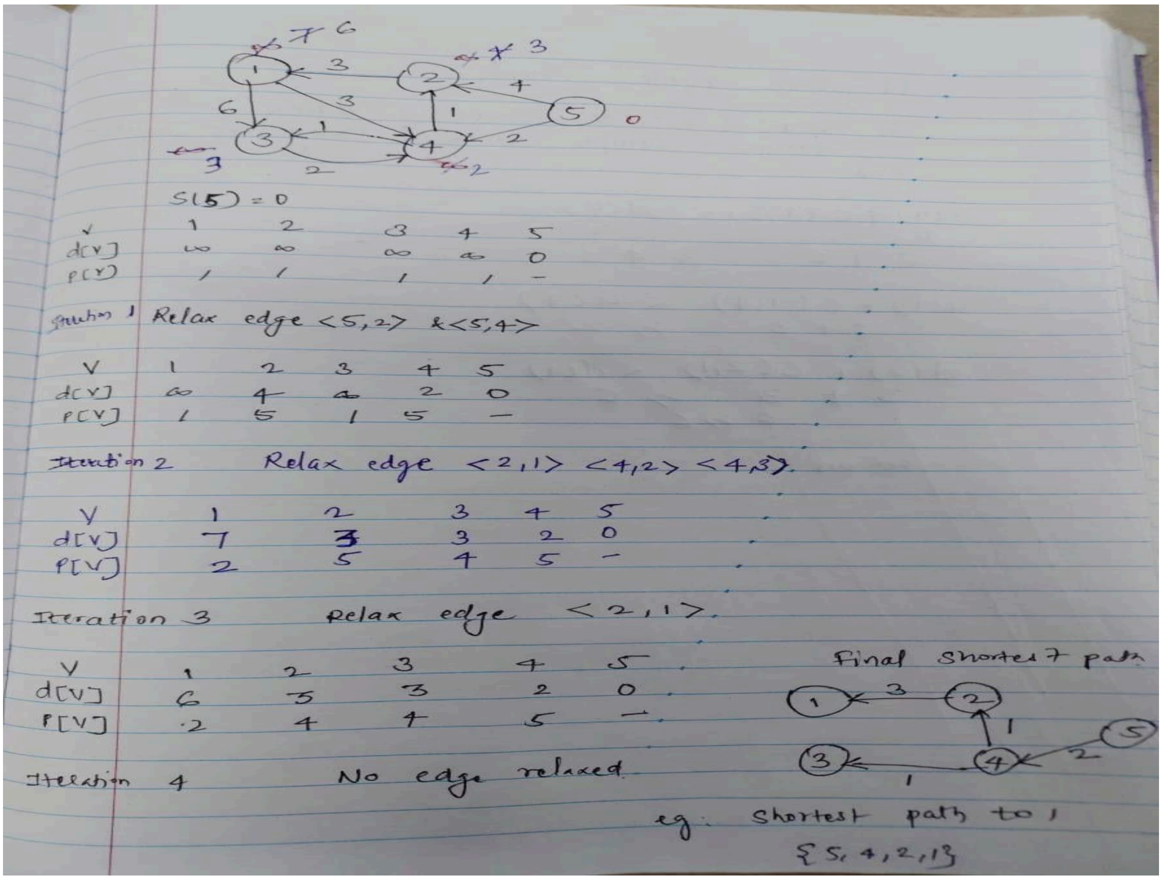


Let all edges are processed in the following order: (B, E), (D, B), (B, D), (A, B), (A, C), (D, C), (B, C), (E, D). We get the following distances when all edges are processed the first time. The first row shows initial distances. The second row shows distances when edges (B, E), (D, B), (B, D) and (A, B) are processed. The third row shows distances when (A, C) is processed. The fourth row shows when (D, C), (B, C) and (E, D) are processed.

A	B	C	D	E
0	∞	∞	∞	∞
0	-1	∞	∞	∞
0	-1	4	∞	∞
0	-1	2	∞	∞
0	-1	2	∞	1
0	-1	2	1	1
0	-1	2	-2	1



The second iteration guarantees to give all shortest paths which are at most 2 edges long. The algorithm processes all edges 2 more times. The distances are minimized after the second iteration, so third and fourth iterations don't update the distances.



S(5) = 0

v	1	2	3	4	5
d[v]	∞	∞	∞	∞	0
p[v]	/	/	/	/	–

Iteration 1 Relax edge <5,2> & <5,4>

v	1	2	3	4	5
d[v]	∞	4	∞	2	0
p[v]	/	5	/	5	–

Iteration 2 Relax edge <2,1> <4,2> <4,3>.

v	1	2	3	4	5
d[v]	7	3	3	2	0
p[v]	2	5	4	5	–

Iteration 3 Relax edge <2,1>.

v	1	2	3	4	5
d[v]	6	3	3	2	0
p[v]	2	4	4	5	–

Iteration 4 No edge relaxed

Final shortest path

eg. shortest path to 1 {5, 4, 2, 1}

Algorithm:

function Bellman_Ford(list vertices, list edges, vertex source, distance[], parent[])

// Step 1 – initialize the graph. In the beginning, all vertices weight of
// INFINITY and a null parent, except for the source, where the weight is 0

```
for each vertex v in vertices
   distance[v] = INFINITY
   parent[v] = NULL

distance[source] = 0
// Step 2 – relax edges repeatedly
   for i = 1 to V-1    // V – number of vertices
      for each edge (u, v) with weight w
         if (distance[u] + w) is less than distance[v]
            distance[v] = distance[u] + w
            parent[v] = u

// Step 3 – check for negative-weight cycles
```

for each edge (u, v) with weight w
  if (distance[u] + w) is less than distance[v]
    return "Graph contains a negative-weight cycle"

return distance[], parent[]

Output:

Shortest path from source (5)

Vertex 5 -> cost=0 parent=0

Vertex 1-> cost=6 parent=2

Vertex 2-> cost=3 parent=4

Vertex 3-> cost =3 parent =4

Vertex 4-> cost =2 paren=5

Implementation:
```
#include <stdio.h>
#include <stdlib.h>
#include <limits.h>

// Structure to represent a weighted edge in the graph
struct Edge {
   int src, dest, weight;
};

// Structure to represent a directed, weighted graph
struct Graph {
   int V, E;
   struct Edge* edge;
```

```
};

// Create a graph with V vertices and E edges
struct Graph* createGraph(int V, int E) {
   struct Graph* graph = (struct Graph*)malloc(sizeof(struct Graph));
   graph->V = V;
   graph->E = E;
   graph->edge = (struct Edge*)malloc(E * sizeof(struct Edge));
   return graph;
}

// Bellman-Ford algorithm function
void BellmanFord(struct Graph* graph, int src) {
   int V = graph->V;
   int E = graph->E;
   int dist[V];

   // Initialize distances from source to all other vertices as INFINITE
   for (int i = 0; i < V; i++)
      dist[i] = INT_MAX;
   dist[src] = 0;

   // Relax all edges V-1 times
   for (int i = 1; i <= V - 1; i++) {
      for (int j = 0; j < E; j++) {
         int u = graph->edge[j].src;
         int v = graph->edge[j].dest;
         int weight = graph->edge[j].weight;
         if (dist[u] != INT_MAX && dist[u] + weight < dist[v])
            dist[v] = dist[u] + weight;
```

```
        }
    }

    // Check for negative weight cycles
    for (int i = 0; i < E; i++) {
        int u = graph->edge[i].src;
        int v = graph->edge[i].dest;
        int weight = graph->edge[i].weight;
        if (dist[u] != INT_MAX && dist[u] + weight < dist[v]) {
            printf("Graph contains negative weight cycle\n");
            return;
        }
    }

    // Print shortest distances
    printf("Vertex   Distance from Source\n");
    for (int i = 0; i < V; ++i)
        printf("%d \t\t %d\n", i, dist[i]);
}

int main() {
    int V, E, src;
    printf("Enter number of vertices and edges: ");
    scanf("%d %d", &V, &E);

    struct Graph* graph = createGraph(V, E);

    printf("Enter source vertex: ");
    scanf("%d", &src);
```

```
    printf("Enter edge details (source destination weight):\n");
    for (int i = 0; i < E; i++)
        scanf("%d %d %d", &graph->edge[i].src, &graph->edge[i].dest,
&graph->edge[i].weight);


    BellmanFord(graph, src);


    return 0;
}
```

Conclusion: Single Source Shortest Path: Bellman Ford has been successfully implemented.

Experiment No. 9
Travelling Salesperson Problem using Dynamic Approach
Date of Performance:
Date of Submission:

Experiment No. 9

Title: Travelling Salesman Problem

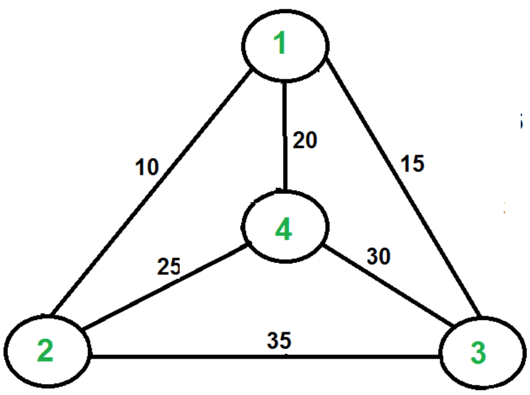
Aim: To study and implement Travelling Salesman Problem.

Objective: To introduce Dynamic Programming approach

Theory:

The **Traveling Salesman Problem (TSP)** is a classic optimization problem in which a salesperson needs to visit a set of cities exactly once and return to the starting city while minimizing the total distance traveled.

Given a set of cities and the distance between every pair of cities, find the **shortest possible route** that visits every city exactly once and returns to the starting point.



For example, consider the graph shown in the figure on the right side. A TSP tour in the graph is 1-2-4-3-1. The cost of the tour is 10+25+30+15 which is 80. The problem is a famous NP-hard problem. There is no polynomial-time know solution for this problem. The following are different solutions for the traveling salesman problem.

Naive Solution:

1) Consider city 1 as the starting and ending point.

2) Generate all (n-1)! Permutations of cities.

3) Calculate the cost of every permutation and keep track of the minimum cost permutation.

4) Return the permutation with minimum cost.

Time Complexity: ?(n!)

Dynamic Programming:
Let the given set of vertices be {1, 2, 3, 4,.n}. Let us consider 1 as starting and ending point of output. For every other vertex I (other than 1), we find the minimum cost path with 1 as the starting point, I as the ending point, and all vertices appearing exactly once. Let the cost of this path cost (i), and the cost of the corresponding Cycle would cost (i) + dist(i, 1) where dist(i, 1) is the distance from I to 1. Finally, we return the minimum of all [cost(i) + dist(i, 1)] values. This looks simple so far.

Now the question is how to get cost(i)? To calculate the cost(i) using Dynamic Programming, we need to have some recursive relation in terms of sub-problems.

Let us define a term *C(S, i) be the cost of the minimum cost path visiting each vertex in set S exactly once, starting at 1 and ending at i.* We start with all subsets of size 2 and calculate C(S, i) for all subsets where S is the subset, then we calculate C(S, i) for all subsets S of size 3 and so on. Note that 1 must be present in every subset.

```
If size of S is 2, then S must be {1, i},

 C(S, i) = dist(1, i)

Else if size of S is greater than 2.

 C(S, i) = min { C(S-{i}, j) + dis(j, i)} where j belongs to S, j !=
i and j != 1.
```

Implemenation:

#include <stdio.h>

#include <stdlib.h>

#include <limits.h>

#define MAX_CITIES 10

int numCities;

int distance[MAX_CITIES][MAX_CITIES];

```
int memo[MAX_CITIES][1 << MAX_CITIES];


int min(int a, int b) {
   return (a < b) ? a : b;
}


int tsp(int currentCity, int visited) {
   if (visited == (1 << numCities) - 1) // all cities visited
      return distance[currentCity][0];


   if (memo[currentCity][visited] != -1)
      return memo[currentCity][visited];


   int minCost = INT_MAX;
   for (int nextCity = 0; nextCity < numCities; nextCity++) {
      if (!(visited & (1 << nextCity))) {
            int cost = distance[currentCity][nextCity] + tsp(nextCity, visited | (1 << nextCity));
         minCost = min(minCost, cost);
      }
   }


   memo[currentCity][visited] = minCost;
```

```
    return minCost;
}


int main() {
    printf("Enter the number of cities (max %d): ", MAX_CITIES);
    scanf("%d", &numCities);

    printf("Enter the distances between cities:\n");
    for (int i = 0; i < numCities; i++) {
        for (int j = 0; j < numCities; j++) {
            scanf("%d", &distance[i][j]);
        }
    }

    // Initialize memoization array
    for (int i = 0; i < numCities; i++) {
        for (int j = 0; j < (1 << numCities); j++) {
            memo[i][j] = -1;
        }
    }

    int minCost = tsp(0, 1); // start from city 0
    printf("Minimum cost for visiting all cities: %d\n", minCost);
```

```
    return 0;
}
```

Conclusion: Travelling Salesman Problem has been successfully implemented.

Experiment No. 10
Sum of Subset using Backtracking
Date of Performance:
Date of Submission:

Title: Sum of Subset

Aim: To study and implement Sum of Subset problem

Objective: To introduce Backtracking methods

Theory:

Backtracking is finding the solution of a problem whereby the solution depends on the previous steps taken. For example, in a maze problem, the solution depends on all the steps you take one-by-one. If any of those steps is wrong, then it will not lead us to the solution. In a maze problem, we first choose a path and continue moving along it. But once we understand that the particular path is incorrect, then we just come back and change it. This is what backtracking basically is.

In backtracking, we first take a step and then we see if this step taken is correct or not i.e., whether it will give a correct answer or not. And if it doesn't, then we just come back and change our first step. In general, this is accomplished by recursion. Thus, in backtracking, we first start with a partial sub-solution of the problem (which may or may not lead us to the solution) and then check if we can proceed further with this sub-solution or not. If not, then we just come back and change it.

Thus, the general steps of backtracking are:

- start with a sub-solution
- check if this sub-solution will lead to the solution or not
- If not, then come back and change the sub-solution and continue again.

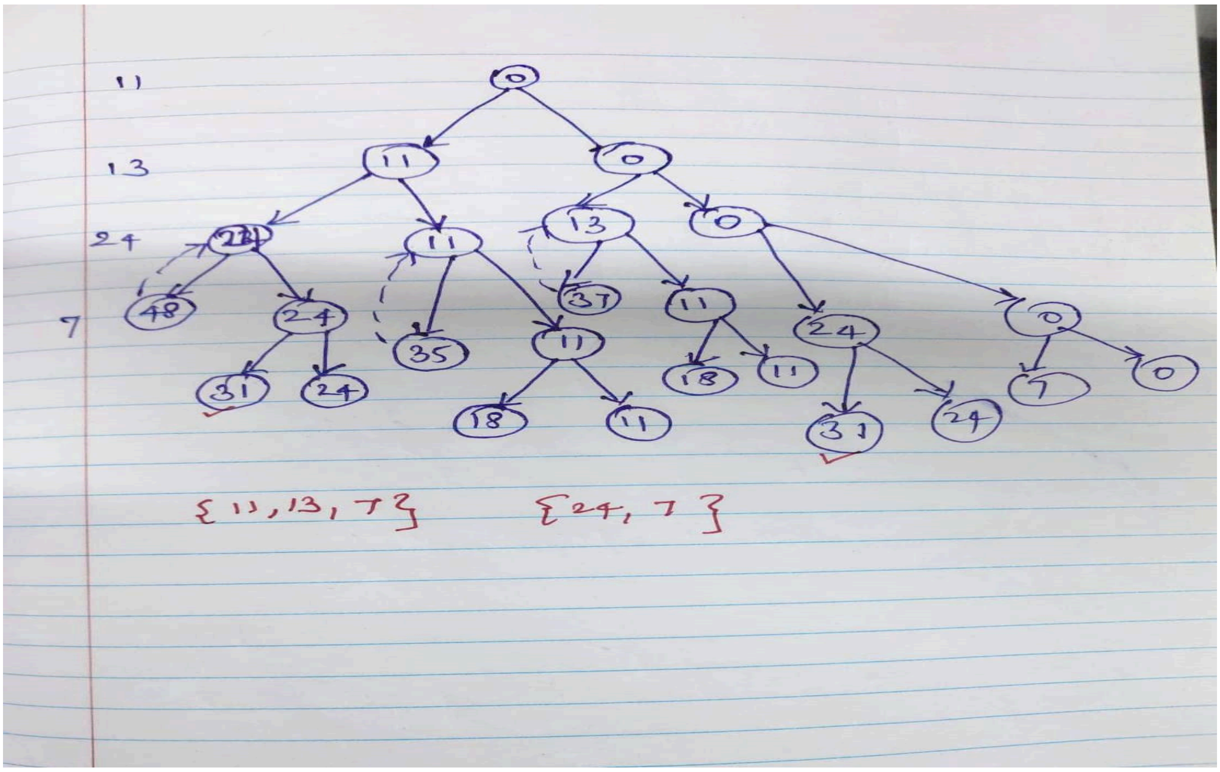
The subset sum problem is a classic optimization problem that involves finding a subset of a given set of positive integers whose sum matches a given target value. More formally, given a set of non-negative integers and a target sum, we aim to determine whether there exists a subset of the integers whose sum equals the target.

Let's consider an example to better understand the problem. Suppose we have a set of integers [1, 4, 6, 8, 2] and a target sum of 9. We need to determine whether there exists a subset within the given set whose sum equals the target, in this case, 9. In this example, the subset [1, 8] satisfies the condition, as their sum is indeed 9.

Solving Subset Sum with Backtracking

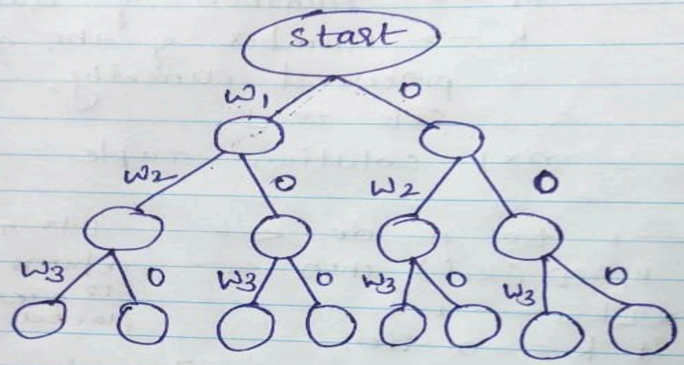
To solve the subset, sum problem using backtracking, we will follow a recursive approach. Here's an outline of the algorithm:

1. Sort the given set of integers in non-decreasing order.
2. Start with an empty subset and initialize the current sum as 0.
3. Iterate through each integer in the set:
    - Include the current integer in the subset.
    - Increment the current sum by the value of the current integer.
    - Recursively call the algorithm with the updated subset and current sum.
    - If the current sum equals the target sum, we have found a valid subset.
    - Backtrack by excluding the current integer from the subset.
    - Decrement the current sum by the value of the current integer.
4. If we have exhausted all the integers and none of the subsets sum up to the target, we conclude that there is no valid subset.


11
13
24
7
0
11
0
24
11
13
0
48
24
35
37
11
24
0
31
24
11
18
11
7
0
18
11
31
24
{11, 13, 7}
{24, 7}

State space tree for $n = 3$

* Any path from the root to leaf forms a subset.



Q. Solve the sum of subset problem using backtracking strategy for the following data $n = 4$
$W = (w_1, w_2, w_3, w_4) = (11, 13, 24, 7)$
and $M = 31$

Subset Items	condition	Comment
{ }	0	Initial condition
{11}	11 < 31	Add next element
{11, 13}	24 < 31	Add next element
{11, 13, 24}	48 < 31	Sub set exceeds sum so backtrack
{11, 13, 7}	31	Solution found

Implementation:

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

// Function to check if there exists a subset with given sum using dynamic programming
bool isSubsetSum(int set[], int n, int sum) {
   bool subset[n + 1][sum + 1];

   // If sum is 0, then answer is true
```

```
    for (int i = 0; i <= n; i++)
        subset[i][0] = true;

    // If sum is not 0 and set is empty, then answer is false
    for (int i = 1; i <= sum; i++)
        subset[0][i] = false;

    // Fill the subset table in bottom-up manner
    for (int i = 1; i <= n; i++) {
        for (int j = 1; j <= sum; j++) {
            if (j < set[i - 1])
                subset[i][j] = subset[i - 1][j];
            else
                subset[i][j] = subset[i - 1][j] || subset[i - 1][j - set[i - 1]];
        }
    }

    // Return the value of subset[n][sum]
    return subset[n][sum];
}

// Main function
int main() {
    int set[] = {3, 34, 4, 12, 5, 2}; // Example set
    int sum = 9; // Example target sum
    int n = sizeof(set) / sizeof(set[0]);

    if (isSubsetSum(set, n, sum))
        printf("Found a subset with sum equal to %d\n", sum);
    else
```

```
        printf("No subset found with sum equal to %d\n", sum);

    return 0;
}
```

Conclusion: The Sum of Subset problem has been implemented.

Experiment No. 11
15 puzzle problem
Date of Performance:
Date of Submission:

Experiment No. 11

Title: 15 Puzzle

Aim: To study and implement 15 puzzle problem

Objective: To introduce Backtracking and Branch-Bound methods

Theory:

The 15 puzzle problem is invented by sam loyd in 1878.

- In this problem there are 15 tiles, which are numbered from 0 – 15.
- The objective of this problem is to transform the arrangement of tiles from initial arrangement to a goal arrangement.
- The initial and goal arrangement is shown by following figure.

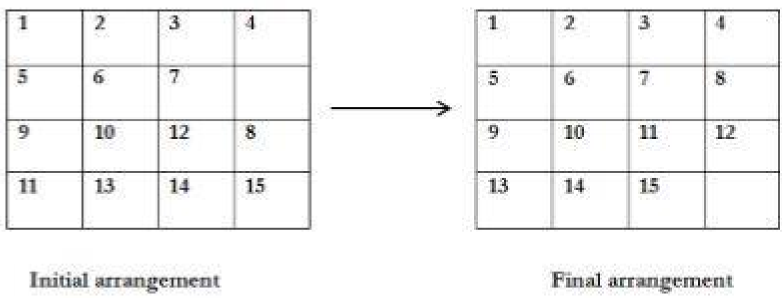
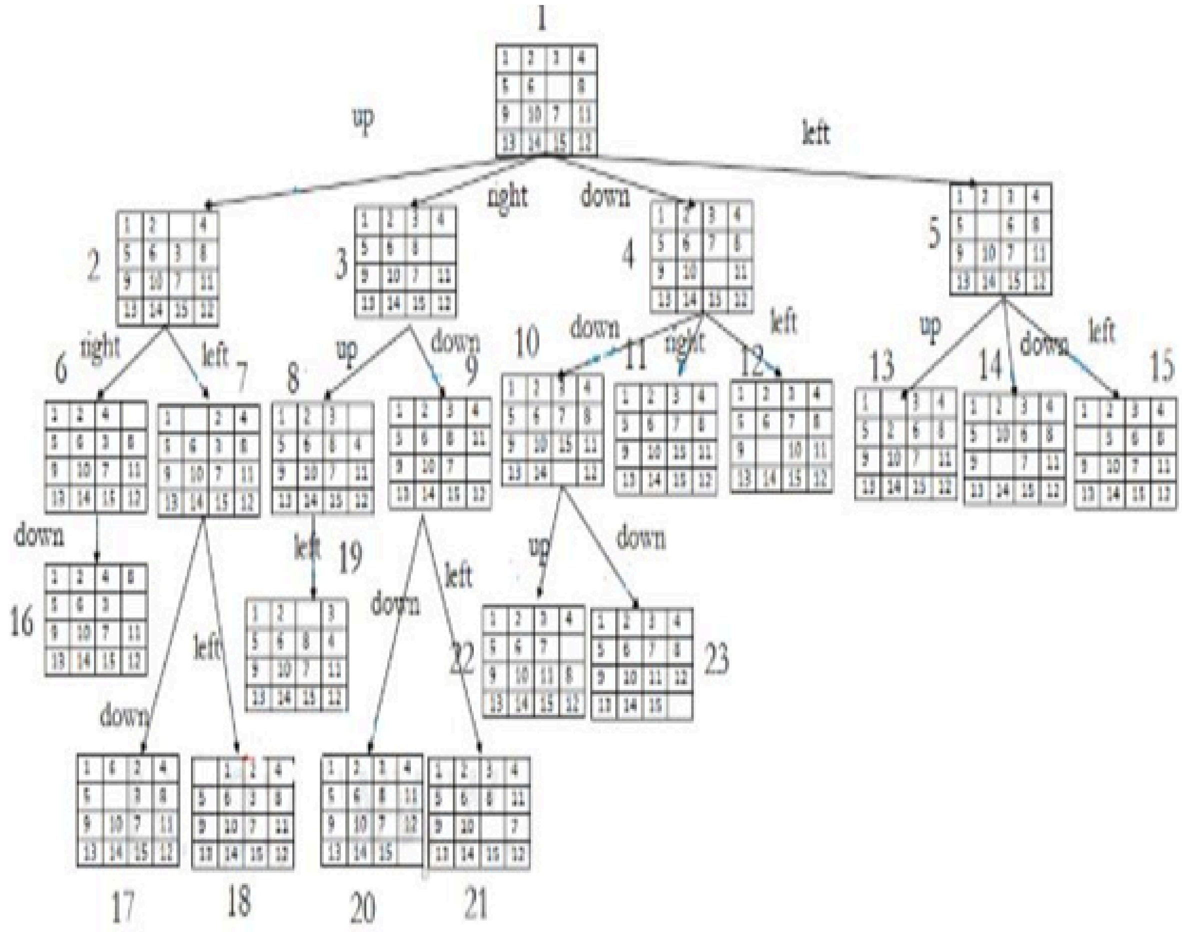


Figure 12

- There is always an empty slot in the initial arrangement.

- The legal moves are the moves in which the tiles adjacent to ES are moved to either left, right, up or down.
- Each move creates a new arrangement in a tile.
- These arrangements are called as states of the puzzle.
- The initial arrangement is called as initial state and goal arrangement is called as goal state.
- The state space tree for 15 puzzle is very large because there can be 16! Different arrangements.
- A partial state space tree can be shown in figure.
- In state space tree, the nodes are numbered as per the level.
- Each next move is generated based on empty slot positions.
- Edges are label according to the direction in which the empty space moves.
- The root node becomes the E – node.
- The child node 2, 3, 4 and 5 of this E – node get generated.
- Out of which node 4 becomes an E – node. For this node the live nodes 10, 11, 12 gets generated.
- Then the node 10 becomes the E – node for which the child nodes 22 and 23 gets generated.
- Finally we get a goal state at node 23.
- We can decide which node to become an E – node based on estimation formula.

Example:



Implementation:

```
#include <stdio.h>

#include <stdlib.h>

#include <stdbool.h>

#include <string.h>


#define N 4
```

```
// Structure to represent a state of the puzzle
typedef struct {
    int puzzle[N][N]; // Configuration of the puzzle
    int x, y;         // Position of the blank tile
    char path[50];    // Path taken to reach this state
} State;

// Structure to represent a node in the BFS queue
typedef struct {
    State state;
    int distance; // Distance from the initial state
} Node;

// Function to swap two integers
void swap(int* a, int* b) {
    int temp = *a;
    *a = *b;
    *b = temp;
}

// Function to check if a state is the goal state
bool isGoalState(State state) {
```

```
    int value = 1;
    for (int i = 0; i < N; i++) {
        for (int j = 0; j < N; j++) {
            if (state.puzzle[i][j] != value % (N * N)) {
                return false;
            }
            value++;
        }
    }
    return true;
}

// Function to print the path taken to reach the goal state
void printPath(State state) {
    printf("Path to the goal state:\n%s\n", state.path);
}

// Function to check if a move is valid
bool isValidMove(int x, int y) {
    return (x >= 0 && x < N && y >= 0 && y < N);
}

// Function to perform BFS to solve the 15 Puzzle problem
```

```
void solvePuzzle(State initialState) {
    // Define the possible moves (up, down, left, right)
    int dx[] = {-1, 1, 0, 0};
    int dy[] = {0, 0, -1, 1};
    char dir[] = {'U', 'D', 'L', 'R'};

    // Initialize the BFS queue
    Node queue[100000];
    int front = 0, rear = 0;
    queue[rear++] = (Node){initialState, 0};

    // Perform BFS
    while (front < rear) {
        Node currentNode = queue[front++];
        State currentState = currentNode.state;
        int currentDistance = currentNode.distance;

        // Check if current state is the goal state
        if (isGoalState(currentState)) {
            printPath(currentState);
            return;
        }
```

```
        // Explore all possible moves from the current state
        for (int i = 0; i < 4; i++) {
            int newX = currentState.x + dx[i];
            int newY = currentState.y + dy[i];

            // Check if the new position is valid
            if (isValidMove(newX, newY)) {
                // Create a new state by swapping the blank tile with the adjacent tile
                State newState = currentState;
                swap(&newState.puzzle[currentState.x][currentState.y],
&newState.puzzle[newX][newY]);
                newState.x = newX;
                newState.y = newY;
                // Update the path
                newState.path[currentDistance] = dir[i];
                newState.path[currentDistance + 1] = '\0';

                // Add the new state to the BFS queue
                queue[rear++] = (Node){newState, currentDistance + 1};
            }
        }
    }
```

```
    printf("No solution found.\n");
}


int main() {
    State initialState;
    int puzzle[N][N] = {
        {1, 2, 3, 4},
        {5, 6, 7, 8},
        {9, 10, 11, 12},
        {13, 14, 0, 15}
    };

    // Find the position of the blank tile
    for (int i = 0; i < N; i++) {
        for (int j = 0; j < N; j++) {
            initialState.puzzle[i][j] = puzzle[i][j];
            if (puzzle[i][j] == 0) {
                initialState.x = i;
                initialState.y = j;
            }
        }
    }
    initialState.path[0] = '\0';
```

```
    solvePuzzle(initialState);


    return 0;
}
```

Conclusion: The 15 Puzzle problem has been implemented.

Experiment No. 12
Naïve String matching
Date of Performance:
Date of Submission:

Experiment No. 12

Title: Naïve String matching

Aim: To study and implement Naïve string matching Algorithm

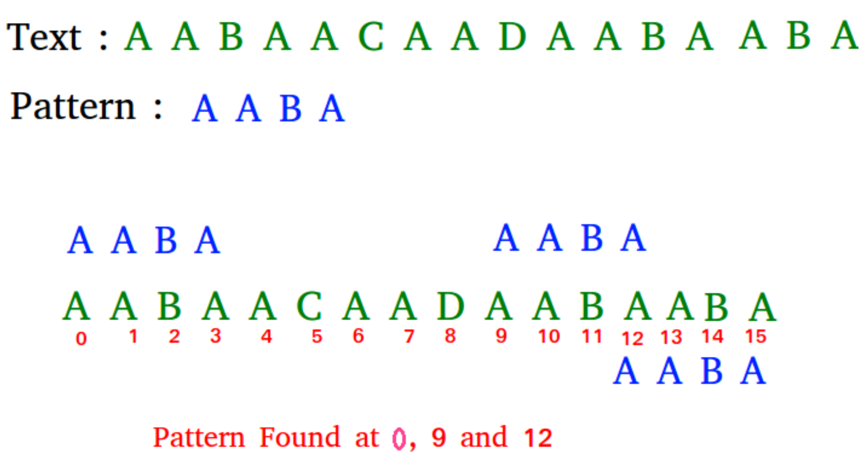
Objective: To introduce String matching methods

Theory:

The naïve approach tests all the possible placement of Pattern P [1.......m] relative to text T [1......n]. We try shift s = 0, 1.......n-m, successively and for each shift s. Compare T [s+1.......s+m] to P [1......m].

The naïve algorithm finds all valid shifts using a loop that checks the condition P [1.......m] = T [s+1.......s+m] for each of the n - m +1 possible value of s.

Example:



Algorithm:

THE NAIVE ALGORITHM

The naive algorithm finds all valid shifts using a loop that checks the condition P[1….m]=T[s+1…. s+m] for each of the n-m+1 possible values of s.(P=pattern , T=text/string , s=shift)

NAIVE-STRING-MATCHER(T,P)

1) n = T.length
2) m = P.length
3) **for** s=0 to n-m
4)   **if** P[1…m]==T[s+1….s+m]
5)   printf" Pattern occurs with shift " s

Implementation:

```
#include <stdio.h>

#include <string.h>


void naiveStringMatch(char text[], char pattern[]) {
```

```
    int m = strlen(pattern);
    int n = strlen(text);

    for (int i = 0; i <= n - m; i++) {
        int j;
        for (j = 0; j < m; j++) {
            if (text[i + j] != pattern[j])
                break;
        }

        if (j == m) {
            printf("Pattern found at index %d\n", i);
        }
    }
}

int main() {
    char text[] = "ABABDABACDABABCABAB";
    char pattern[] = "ABABCABAB";

    printf("Text: %s\n", text);
    printf("Pattern: %s\n", pattern);
```

```
    printf("Occurrences:\n");
    naiveStringMatch(text, pattern);


    return 0;
}
```

Conclusion: Naïve string-matching algorithm has been successfully implemented.