LAB MANUAL

Laboratory Practice III

(DESIGN AND ANALYSIS OF ALGORITHMS)

Year	**:**	**2022 - 2023**
Course Code	**:**	**410246**
Semester	**:**	**VII**
Branch	**:**	**Computer Engineering**

Prepared by:

Ms. Manisha Ambekar

Dr. D Y Patil Pratishthan's
Dr. D.Y. Patil Institute of Engineering, Management and Research,
Akurdi, Pune

1. PROGRAM OUTCOMES:

PROGRAM OUTCOMES (POS)	
PO-1	Apply the knowledge of mathematics, science, engineering fundamentals, and an engineeringspecialization to the solution of complex engineering problems**(Engineering knowledge).**
PO-2	Identify, formulate, review research literature, and analyze complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineeringsciences **(Problem analysis)**.
PO-3	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 thecultural, societal, and environmental considerations **(Design/development of solutions)**.
PO-4	Use research-based knowledge and research methods including design of experiments, analysis andinterpretation of data, and synthesis of the information to provide valid conclusions **(Conduct investigations of complex problems)**.
PO-5	Create, select, and apply appropriate techniques, resources, and modern engineering and IT toolsincluding prediction and modeling to complex engineering activities with an understanding of the limitations **(Modern tool usage)**.
PO-6	Apply reasoning informed by the contextual knowledge to assesssocietal, health, safety, legal andcultural issues and the consequent responsibilities relevant to the professional engineering practice **(The engineer and society)**.
PO-7	Understand the impact of the professional engineering solutions in societal and environmental contexts, and demonstrate the knowledge of, and need for sustainable development **(Environmentand sustainability)**.
PO-8	Apply ethical principles and commit to professional ethics and responsibilities and norms of the engineering practice **(Ethics)**.
PO-9	Function effectively as an individual, and as a member or leader in diverse teams, and inmultidisciplinary settings **(Individual and team work)**.
PO-10	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 **(Communication)**.
PO-11	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 **(Project management and finance)**.
PO-12	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 **(Life-long learning)**.

2. PROGRAM SPECIFIC OUTCOMES

PROGRAM SPECIFIC OUTCOMES (PSO's)	
PSO-1	**Professional Skills:** The ability to understand, analyze and develop computer programs in the areasrelated to algorithms, system software, multimedia, web design, big data analytics, and networking for efficient design of computer-based systems of varying complexity.
PSO-2	**Problem-Solving Skills:** The ability to apply standard practices and strategies in software project development using open-ended programming environments to deliver a quality product for businesssuccess.
PSO-3	**Successful Career and Entrepreneurship:** The ability to employ modern computer languages, environments, and platforms in creating innovative career paths to be an entrepreneur, and a zest forhigher studies.

Companion Course: Design and Analysis of Algorithms (410241),
Machine Learning (410242),
Block chain Technology (410243)

3. COURSE OBJECTIVES:

- Learn effect of data preprocessing on the performance of machine learning algorithms
- Develop in depth understanding for implementation of the regression models.
- Implement and evaluate supervised and unsupervised machine learning algorithms.
- Analyze performance of an algorithm.
- Learn how to implement algorithms that follow algorithm design strategies namely Divide and Conquer, greedy, dynamic programming, backtracking, branch and bound.
- Understand and explore the working of Block chain technology and its applications

4. COURSE OUTCOMES:

After completion of the course, students will be able to
CO1: Apply preprocessing techniques on datasets.
CO2: Implement and evaluate linear regression and random forest regression models.
CO3: Apply and evaluate classification and clustering techniques.
CO4: Analyze performance of an algorithm.
CO5: Implement an algorithm that follows one of the following algorithm design strategies: Divide and conquer, greedy, dynamic programming, backtracking, branch and bound.
CO6: Interpret the basic concepts in Block chain technology and its applications

Course Contents
Group A: Design and Analysis of Algorithms

5. ATTAINMENT OF PROGRAM OUTCOMES AND PROGRAM SPECIFIC OUTCOMES:

S.No	Experiment	Program Outcomes Attained	Program Specific Outcomes Attained
1	**Write a program non-recursive and recursive program to calculate Fibonacci numbers and analyze their time and space complexity**	PO-2, PO-3	PSO-1
2	**Write a program to implement Huffman Encoding using a greedy strategy**	PO-3	PSO-1, PSO2
3	**Program to implement fractional knapsack problem using greedy method**	PO-3	PSO-1, PSO2
4	**Implement 0/1 Knapsack problem using Dynamic Programming.**	PO-3, PO-12	PSO-1 , PSO2
5	**Implement N Queen's problem using Back Tracking.**	PO-3	PSO-1, PSO2
6	**Mini Project - Implement the Naive string matching algorithm and Rabin-Karp algorithm for string matching. Observe difference in working of both the algorithms for the same input.**	PO-3, PO-12	PSO-1 , PSO2

6. MAPPING COURSE OBJECTIVES LEADING TO THE ACHIEVEMENT OF PROGRAM OUTCOMES

Course Objectives	Program Outcomes												gram Specific Outcomes		
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO 10	PO 11	PO 12	PSO1	PSO2	PSO3
4	3	2	2	-	1	-	-	1	2	-	2	2	2	2	-
5	3	2	3	-	1	-	-	1	2	-	-	2	3	3	-

7. SOFTWARE AND HARDWARE REQUIREMENTS:

HARDWARE:
Desktop Computer Systems

SOFTWARE:
Application Software: C Programming Compiler

INDEX

Assignmentt-1

OBJECTIVE:

To write a non-recursive and recursive program to calculate Fibonacci numbers and analyze their time and space complexity

RESOURCES:

Dev C++

PROGRAM LOGIC:

The Fibonacci series can be described using the mathematical equation F(n)=F(n-1)+F(n-2)F(n)=F(n−1)+F(n−2), with the condition F(1)=0 and F(2)=1. The sum of the previous two numbers in the sequence is the next number of the sequence. The Fibonacci series can be implemented in C **using recursion or without using recursion**.

PROCEDURE:

1. Create: Open Dev C++, write a program after that save the program with .c extension.
2. Compile: Alt + F9
3. Execute: Ctrl + F10

SOURCE CODE:

1. Using Recursion

```
include<stdio.h>

int fib(int n) {
  if (n == 1)
    return 0; //First digit in the series is 0
  else if (n == 2)
    return 1; //Second digit in the series is 1
  else
    return (fib(n - 1) + fib(n - 2)); //Sum of previous two numbers in the series gives the next number in the
series
}

int main() {
  int n = 5;
   int i;
  printf("The fibonacci series is :\n");
  for (i = 1; i <= n; i++) {
    printf("%d ", fib(i));
  }
}
```

Explanation:

In the above code, we created a function named fib(), which has an integer as the parameter and return value data type. In the main function, we iterate over a loop from 1 to n times, and at each iteration called the fib() function. In fib() function, if the parameter passed is 0 or 1, we will return the same value otherwise, we will return the sum of recursive calls with parameter values one and two less than our current parameter, which is **fib(i-1)+fib(i-2)**.

Time and Space Complexity of Recursive Method

- The time complexity of the above code is **T(2^N), i.e., exponential**.
- The Space complexity of the above code is **O(N) for a recursive series**.

2. without Recursion

```
#include<stdio.h>
int fib(int n) {
  int arr[5];
  int i;

  arr[0] = 0; // First term is zero
  arr[1] = 1; // Second term is one
  for (i = 2; i <= n; i++) {
    arr[i] = arr[i - 1] + arr[i - 2]; //Calculating the sum of previous two fibonacci numbers
  }
  for (i = 0; i <= n - 1; i++) {
    printf("%d ", arr[i]);
  }
}

int main() {
  int n = 5;
  printf("The Fibonacci series is : \n");
  fib(n);
  return 0;
}
```

Explanation In the above code, In the main() function, We called the fib() function with n as a parameter. The value of n is initialized to 5.

In the fib() function, We create an array of size n, in our case an array of size 5 to hold the Fibonacci numbers. The first and second element in the array is initialized to 0 and 1, respectively. Later we used for loop to find the other elements of the array i.e the Fibonacci numbers using the formula **arr[i] = arr[i-1] + arr[i-2]**. Later we will print all the elements in the array.

Time Complexity and Space Complexity of Dynamic Programming

The time complexity of the above code is T(N), i.e., linear. We have to find the sum of two terms, and it is repeated n times depending on the value of n.
The space complexity of the above code is O(N).

INPUT/ OUTPUT:

1. Using Recursion

The fibonacci series is :
0 1 1 2 3

2. without using Recursion

Output
The Fibonacci series is :
0 1 1 2 3

Assignment -2

OBJECTIVE:

Write a program to implement Huffman Encoding using a greedy strategy

RESOURCES:

Dev C++

PROGRAM LOGIC:

Huffman coding is a lossless data compression algorithm. The idea is to assign variable-length codes to input characters, lengths of the assigned codes are based on the frequencies of corresponding characters. The most frequent character gets the smallest code and the least frequent character gets the largest code Huffman Coding is a technique of compressing data to reduce its size without losing any of the details

PROCEDURE:

- Create: Open Dev C++, write a program after that save the program with .c extension.
- Compile: Alt + F9
- Execute: Ctrl + F10

SOURCE CODE:

```
#include <stdio.h>
#include <stdlib.h>
// node
/*

        _____
        | data|
        | freq|
        |_____|
left ch./       \right chlid address
  _____/         \ _____
 | data|         | data|
 | freq|         | freq|
 |_____|         |_____|
*/
typedef struct node
{
  int frequency;
  char data;
  struct node *left;
  struct node *right;
}node;
int heap_array_size = 100; // size of array storing heap
int heap_size = 0;
```

```
const int INF = 100000;
//function to swap nodes
void swap( node *a, node *b ) {
  node t;
  t = *a;
  *a = *b;
  *b = t;
}
/*
  function to print tree
  https://www.codesdope.com/blog/article/binary-tree-in-c-linked-representation-traversals/
*/
void inorder(struct node *root)
{
  if(root!=NULL) // checking if the root is not null
  {
    inorder(root->left); // visiting left child
    printf(" %d ", root->frequency); // printing data at root
    inorder(root->right);// visiting right child
  }
}
/*
  function for new node
*/
node* new_node(char data, int freq) {
  node *p;
  p = malloc(sizeof(struct node));
  p->data = data;
  p->frequency = freq;
  p->left = NULL;
  p->right = NULL;
  return p;
}
//function to get right child of a node of a tree
int get_right_child(int index) {
  if((((2*index)+1) <= heap_size) && (index >= 1))
    return (2*index)+1;
  return -1;
}
//function to get left child of a node of a tree
int get_left_child(int index) {
    if(((2*index) <= heap_size) && (index >= 1))
        return 2*index;
    return -1;
}
//function to get the parent of a node of a tree
int get_parent(int index) {
  if ((index > 1) && (index <= heap_size)) {
    return index/2;
  }
  return -1;
}
```

```
/*  Functions taken from minimum priority queue
  https://www.codesdope.com/blog/article/priority-queue-using-heap/
  https://www.codesdope.com/blog/article/heap-binary-heap/*/
 void insert(node A[], node* a, int key) {
  heap_size++;
  A[heap_size] = *a;
  int index = heap_size;
  while((index>1) && (A[get_parent(index)].frequency > a->frequency)) {
    swap(&A[index], &A[get_parent(index)]);
    index = get_parent(index);
  }
 }
 node* build_queue(node c[], int size) {
  node* a = malloc(sizeof(node)*heap_array_size); // a is the array to store heap
  int i;
  for(i=0; i<size; i++) {
    insert(a, &c[i], c[i].frequency); // inserting node in array a(min-queue)
  }
  return a;
 }
 void min_heapify(node A[], int index) {
  int left_child_index = get_left_child(index);
  int right_child_index = get_right_child(index);

  // finding smallest among index, left child and right child
  int smallest = index;

  if ((left_child_index <= heap_size) && (left_child_index>0)) {
    if (A[left_child_index].frequency < A[smallest].frequency) {
      smallest = left_child_index;
    }
  }
  if ((right_child_index <= heap_size && (right_child_index>0))) {
    if (A[right_child_index].frequency < A[smallest].frequency) {
      smallest = right_child_index;
    }
  }
  // smallest is not the node, node is not a heap
  if (smallest != index) {
    swap(&A[index], &A[smallest]);
    min_heapify(A, smallest);
  }
 }
 node* extract_min(node A[]) {
  node minm = A[1];
  A[1] = A[heap_size];
  heap_size--;
  min_heapify(A, 1);
  node *z;
  // copying minimum element
  z = malloc(sizeof(struct node));
  z->data = minm.data;
```

```
  z->frequency = minm.frequency;
  z->left = minm.left;
  z->right = minm.right;
  return z; //returning minimum element
}

// Huffman code
node* greedy_huffman_code(node C[]) {
  node *min_queue = build_queue(C, 6); // making min-queue

  while(heap_size > 1) {
    node *h = extract_min(min_queue);
    node *i = extract_min(min_queue);
    node *z;
    z = malloc(sizeof(node));
    z->data = '\0';
    z->left = h;
    z->right = i;
    z->frequency = z->left->frequency + z->right->frequency;
    insert(min_queue, z, z->frequency);
  }
  return extract_min(min_queue);
}

int main() {
  node *a = new_node('a', 42);
  node *b = new_node('b', 20);
  node *c = new_node('c', 5);
  node *d = new_node('d', 10);
  node *e = new_node('e', 11);
  node *f = new_node('f', 12);
  node C[] = {*a, *b, *c, *d, *e , *f};
  node* z = greedy_huffman_code(C);
  inorder(z); //printing tree
  printf("\n");
  return 0;
}
```

Output:

```
42  100  11  23  12  58  5  15  10  35  20


...Program finished with exit code 0
Press ENTER to exit console.
```

Assignment 3

3. Program to implement fractional knapsack problem using greedy method

```
# include<stdio.h>
void knapsack(int n, float weight[], float profit[], float capacity) {
   float x[20], tp = 0;
   int i, j, u;
   u = capacity;
    for (i = 0; i < n; i++)
      x[i] = 0.0;
    for (i = 0; i < n; i++) {
      if (weight[i] > u)
         break;
      else {
         x[i] = 1.0;
         tp = tp + profit[i];
         u = u - weight[i];
      }
   }

   if (i < n)
      x[i] = u / weight[i];
    tp = tp + (x[i] * profit[i]);
    printf("\nThe result vector is:- ");
   for (i = 0; i < n; i++)
      printf("%f\t", x[i]);

   printf("\nMaximum profit is:- %f", tp);
 }
int main() {
   float weight[20], profit[20], capacity;
   int num, i, j;
   float ratio[20], temp;
    printf("\nEnter the no. of objects:- ");
   scanf("%d", &num);
    printf("\nEnter the wts and profits of each object:- ");
   for (i = 0; i < num; i++) {
      scanf("%f %f", &weight[i], &profit[i]);
   }
    printf("\nEnter the capacityacity of knapsack:- ");
   scanf("%f", &capacity);
    for (i = 0; i < num; i++) {
      ratio[i] = profit[i] / weight[i];
   }
    for (i = 0; i < num; i++) {
      for (j = i + 1; j < num; j++) {
         if (ratio[i] < ratio[j]) {
            temp = ratio[j];
            ratio[j] = ratio[i];
            ratio[i] = temp;
```

```
            temp = weight[j];
            weight[j] = weight[i];
            weight[i] = temp;
            temp = profit[j];
            profit[j] = profit[i];
            profit[i] = temp;
          }
        }
      }
      knapsack(num, weight, profit, capacity);
    return(0);
}
```

Output :

```
Enter the no. of objects:- 7
 Enter the wts and profits of each object:-
2 10
3 5
5 15
7 7
1 6
4 18
1 3
 Enter the capacity of knapsack:- 15
 The result vector is:- 1.000000        1.000000        1.000000        1.000000
    1.000000        0.666667        0.000000
 Maximum profit is:- 55.333332
```

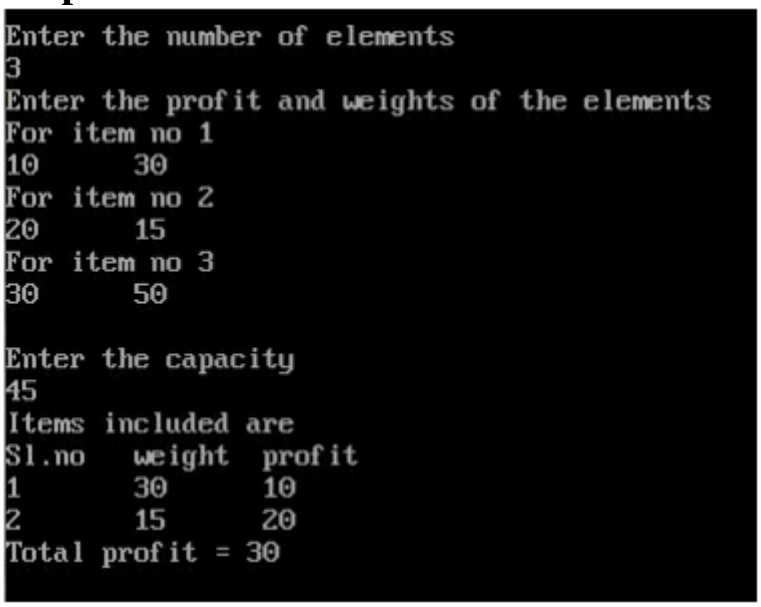
Assignment 4

Implement 0/1 Knapsack problem using Dynamic Programming.

```
#include<stdio.h>
#include<conio.h>
int w[10],p[10],v[10][10],n,i,j,cap,x[10]={0};
int max(int i,int j)
{
return ((i>j)?i:j);
}
int knap(int i,int j)
{
int value;
if(v[i][j]<0)
{
if(j<w[i])
value=knap(i-1,j);
else
value=max(knap(i-1,j),p[i]+knap(i-1,j-w[i]));
v[i][j]=value;
}
return(v[i][j]);
}
void main()
{
int profit,count=0;
clrscr();
printf("\nEnter the number of elements\n");
scanf("%d",&n);
printf("Enter the profit and weights of the elements\n");
for(i=1;i<=n;i++)
{
printf("For item no %d\n",i);
scanf("%d%d",&p[i],&w[i]);
}
printf("\nEnter the capacity \n");
scanf("%d",&cap);
for(i=0;i<=n;i++)
for(j=0;j<=cap;j++)
if((i==0)||(j==0))
v[i][j]=0;
else
v[i][j]=-1;
profit=knap(n,cap);
```

```
i=n;
j=cap;
while(j!=0&&i!=0)
{
if(v[i][j]!=v[i-1][j])
{
x[i]=1;
j=j-w[i];
i--;
}
else
i--;
}
printf("Items included are\n");
printf("Sl.no\tweight\tprofit\n");
for(i=1;i<=n;i++)
if(x[i])
printf("%d\t%d\t%d\n",++count,w[i],p[i]);
printf("Total profit = %d\n",profit);
getch();
}
```

Output



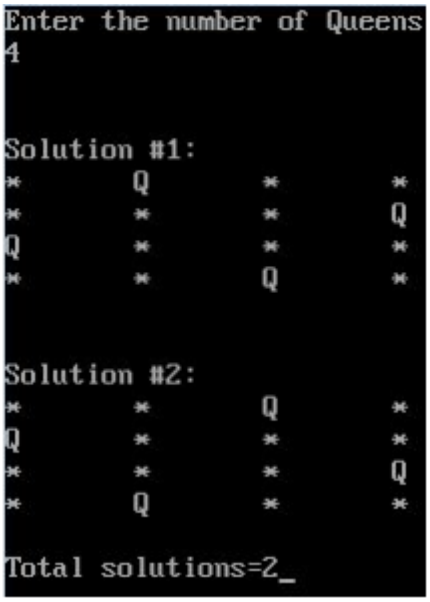
Assignment 5

Implement N Queen's problem using Back Tracking.

```
#include<stdio.h>
#include<conio.h>
#include<math.h>
int a[30],count=0;
int place(int pos)
{
int i;
for(i=1;i<pos;i++)
{
if((a[i]==a[pos])||((abs(a[i]-a[pos])==abs(i-pos))))
return 0;
}
return 1;
}
void print_sol(int n)
{
int i,j;
count++;
printf("\n\nSolution #%d:\n",count);
for(i=1;i<=n;i++)
{
for(j=1;j<=n;j++)
{
if(a[i]==j)
printf("Q\t");
else
printf("*\t");
}
printf("\n");
}
}
void queen(int n)
{
int k=1;
a[k]=0;
while(k!=0)
{
a[k]=a[k]+1;
while((a[k]<=n)&&!place(k))
a[k]++;
if(a[k]<=n)
{
```

```
if(k==n)
print_sol(n);
else
{
k++;
a[k]=0;
}
}
else
k--;
}
}
void main()
{
int i,n;
clrscr();
printf("Enter the number of Queens\n");
scanf("%d",&n);
queen(n);
printf("\nTotal solutions=%d",count);
getch();
}
```

Output:



Mini Project - Implement the Naive string matching algorithm and Rabin-Karp algorithm for string matching. Observe difference in working of both the algorithms for the same input.

String Matching

Pattern matching is the process of checking a perceived sequence of string for the presence of the constituents of some pattern. In contrast to pattern recognition, the match usually has to be exact. The patterns generally have the form sequences of pattern matching include outputting the locations of a pattern within a string sequence, to output some component of the matched pattern, and to substitute the matching pattern with some other string sequence (i.e., search and replace). Pattern matching concept is used in many applications Following figure shows the different applications.

Algorithms used for pattern searching

Naive Pattern Searching
Rabin Karp String Search Algorithm
Knuth–Morris–Pratt algorithm
Boyer–Moore string search algorithm

Naive Pattern Searching

A naive string matching algorithm compares the given pattern against all positions in the given text. Each comparison takes time proportional to the length of the pattern, and the number of positions is proportional to the length of the text. Therefore, the worst-case time for such a method is proportional to the product of the two lengths. In many practical cases, this time can be significantly reduced by cutting short

the comparison at each position as soon as a mismatch is found, but this idea cannot guarantee any speedup.

Technique : Each character of the pattern is compared to a substring of the text which is the length of the pattern, until there is a mismatch or a match.

Code / Algorithm

rough/ naive.c

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

void search(char* pat, char* txt)
{
    int M = strlen(pat);
    int N = strlen(txt);


    for (int i = 0; i <= N - M; i++) {
        int j;


        for (j = 0; j < M; j++)
            if (txt[i + j] != pat[j])
                break;

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


int main()
{
    printf("Enter the text");
    char txt[100] ;
    scanf("%s",txt);
    char pat[100] ;
    printf("Enter the pattern");
    scanf("%s",pat);
    search(pat, txt);
    return 0;
}

```

Time Complexity

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).

The **worst case** of Naive Pattern Searching occurs in when all characters of the text and pattern are same or hen only the last character is different.

txt[] = "AAAAAAAAAAAAAAAAAA";
pat[] = “AAAAA";

txt[] = "AAAAAAAAAAAAAAAAAB";
pat[] = "AAAAB";

The number of comparisons in the 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).

Space Complexity

This is an in-place algorithm. So O(1) auxiliary space is needed.

Rabin–Karp string search algorithm

Rabin-Karp algorithm 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.

Technique : Hashing! 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.

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 / Algorithm

naive.c rk.c DAA/

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

#define d 256 // d is the number of characters in the input alphabet

void search(char pat[], char txt[], int q)
{
    int M = strlen(pat);
    int N = strlen(txt);
    int i, j;
    int p = 0; // hash value for pattern
    int t = 0; // hash value for txt
    int h = 1;
    for (i = 0; i < M-1; i++)
        h = (h*d)%q;

    // Calculate the hash value of pattern and first window of text
    for (i = 0; i < M; i++)
    {
        p = (d*p + pat[i])%q;
        t = (d*t + txt[i])%q;
    }

    for (i = 0; i <= N - M; i++)
    {

        // Check the hash values of current window of text  and pattern. If the hash values match then only  check for characters on by one
        if ( p == t )
        {
            for (j = 0; j < M; j++)
            {
                if (txt[i+j] != pat[j])
                    break;
            }

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

        // Calculate hash value for next window of text: Remove leading digit, add trailing digi
        if ( i < N-M )
        {
            t = (d*(t - txt[i]*h) + txt[i+M])%q;
            if (t < 0)
            t = (t + q);
        }
    }
}

int main()
{
    char txt[100] ;
    printf("Enter the text : ");
    scanf("%s",txt);
    printf("Enter the pattern : ");
    char pat[100] ;
    scanf("%s",pat);
    int q = 101; // A prime number
    search(pat, txt, q);
    return 0;
}
```

Time Complexity

The **average** case running time of the Rabin-Karp algorithm is O(n+m), but its **worst-case** time is O((n-m+1) m).
Best case is O(m).

One of the Worst case of Rabin-Karp algorithm O(mn) 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".

Space Complexity

Space Complexity of Rabin-Karp algorithm is O(m)

Comparison Tables for Algorithms

Different Techniques used by Different Algorithms

Algorithm	Techniques
Naive string search algorithm	Each character of the pattern is compared to a substring of the text which is the length of the pattern, until there is a mismatch or a match.
Rabin–Karp string search algorithm	Hashing

Comparisons of Worst case Complexity of different algorithms

Algorithm	Preprocessing time		Matching time/Searching Phase/Running Time
	Time complexity	Space complexity	
Naive string search algorithm	O(n)	O(1)	O((n-m+1) m)
Rabin–Karp string search algorithm	O(m)	O(m)	Average O(n+m), worst O((n-m+1) m)
Knuth–Morris–Pratt algorithm	O(m)	O(m)	O(m+n)
Boyer–Moore string search algorithm	O(m + |Σ|)	O(m + |Σ|)	Ω(n/m), O(n)