Practical-8

Aim: String Matching Algorithm

Software Requirement: GNU Compiler Collection (GCC), MS Word.

Hardware Requirement: Desktop Computer.

[8.1]

Aim: Suppose you are given a source string S[0 ..n − 1] of length n, consisting of symbols a and b. Suppose that you are given a pattern string P[0 ..m − 1] of length m < n, consisting of symbols a, b, and *, representing a pattern to be found in string S. The symbol * is a "wild card" symbol, which matches a single symbol, either a or b. The other symbols must match exactly. The problem is to output a sorted list M of valid "match positions", which are positions j in S such that pattern P matches the substring S [j..j + |P|− 1]. For example, if S = ababbab and P = ab*, then the output M should be [0, 2].

Implement a straightforward, naive algorithm to solve the problem.

Theory:

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. 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.

Algorithm:

```
naiveAlgorithm(mainString, pattern)
M = [ ]
for s = 0 to n − m
        valid = TRUE
        for j = 0 to m − 1
                if P[j] = ∗ and P[j] = S[s + j]
                        valid = FALSE
        if valid
                M.APPEND(s); return M
```

Code:

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

void naiveAlgorthm(vector<char> text, vector<char> pattern)
{
   int i, j;
   bool valid;
   int textSize = text.size();
   int pattSize = pattern.size();

   vector<int> M;
   for (i = 0; i < (textSize - pattSize); i++)
   {
      valid = true;
      for (j = 0; j < (pattSize - 1); j++)
      {
         if (pattern[j] != '*' && pattern[j] != text[i + j])
            valid = false;
      }
      if (valid)
      {
         M.push_back(i);
      }
   }
   cout << endl << "--------------------------------" << endl;
   for (i = 0; i < M.size(); i++)
   {
      cout << "Pattern found at index: " << M[i] << endl;
   }
}

int main()
{
   int sizeText, sizePattern;
   char temp, temp1;
   vector<char> text;
   vector<char> pattern;

   cout << "Enter Size of Text: ";
   cin >> sizeText;

   cout << "\nEnter Text: ";
   for (int i = 0; i < sizeText; i++)
   {
      cin >> temp;
      text.push_back(temp);
```

```
    }

    cout << "\nEnter Size of Pattern: ";
    cin >> sizePattern;

    cout << "\nEnter Pattern: ";
    for (int i = 0; i < sizePattern; i++)
    {
        cin >> temp1;
        pattern.push_back(temp1);
    }

    naiveAlgorthm(text, pattern);
    return 0;
}
```

Output:

```
Enter Size of Text: 19

Enter Text: 2359023141526739921

Enter Size of Pattern: 5

Enter Pattern: 31415

Enter value of q: 13
--------------------------------

Pattern found at index: 6

--------------------------------
Process exited after 44.95 seconds with return value 0
Press any key to continue . . .
```

Conclusion:

In this practical we performed Naïve String-Matching Algorithm and found out that the time complexity of this particular algorithm is O(m*n) which is the worst-case complexity of String-Matching Algorithm.

[8.2]

Aim: Implement Rabin karp algorithm and test it on the following test cases:

String	Pattern
2359023141526739921	31415 q=13 and q=11
ABAAABCDBBABCDDEBCABC	ABC q=101

Theory:

Rabin-Karp is another pattern searching algorithm to find the pattern in a more efficient way. It also checks the pattern by moving window one by one, but without checking all characters for all cases, it finds the hash value. When the hash value is matched, then only it tries to check each character. This procedure makes the algorithm more efficient.

The time complexity is O(m+n), but for the worst case, it is O(mn).

Input:

Main String: “ABAAABCDBBABCDDEBCABC”, Pattern “ABC”

Output:

Pattern found at position: 4

Pattern found at position: 10

Pattern found at position: 18

Algorithm:

Input − The main text and the pattern. Another prime number of find hash location

Output − location where patterns are found

```
Begin
  patLen := pattern Length
  strLen := string Length
  patHash := 0 and strHash := 0, h := 1
  maxChar := total number of characters in character set

  for index i of all character in pattern, do
    h := (h*maxChar) mod prime
  done

  for all character index i of pattern, do
```

```
    patHash := (maxChar*patHash + pattern[i]) mod prime
    strHash := (maxChar*strHash + text[i]) mod prime
  done

  for i := 0 to (strLen - patLen), do
    if patHash = strHash, then
      for charIndex := 0 to patLen -1, do
        if text[i+charIndex] ≠ pattern[charIndex], then
          break the loop
      done

      if charIndex = patLen, then
        print the location i as pattern found at i position.
    if i < (strLen - patLen), then
      strHash := (maxChar*(strHash – text[i]*h)+text[i+patLen]) mod prime, then
    if strHash < 0, then
      strHash := strHash + prime
  done
End
```

Code:

```
#include <iostream>
#include <vector>
#define MAXCHAR 256
using namespace std;

void rabinKarp(vector<char> text, vector<char> pattern, int q)
{
    int j;
    int textSize = text.size();
    int pattSize = pattern.size();
    int patternHash = 0, textHash = 0, h = 1;

    //calculating h = {d^(M-1)} mod prime
    for (int i = 0; i < pattSize - 1; i++)
    {
        h = (MAXCHAR * h) % q;
    }
    for (int i = 0; i < pattSize; i++)
    {
        //pattern hash value
```

```
        patternHash = (MAXCHAR * patternHash + pattern[i]) % q;

        //hash for first window
        textHash = (MAXCHAR * textHash + text[i]) % q;
    }
    cout << "--------------------------------" << endl;
    for (int i = 0; i <= (textSize - pattSize); i++)
    {
        //when hash values are same check for matching
        if (patternHash == textHash)
        {
            int flag = 1;
            for (j = 0; j < pattSize; j++)
            {
                if (text[i + j] != pattern[j])
                {
                    flag = 0;
                    break;
                }
            }
            //the pattern is found
            if (j == pattSize)
                cout << endl << "Pattern found at index: " << i << endl;
        }
        // find hash value for next window
        if (i < textSize - pattSize)
        {
            textHash = (MAXCHAR * (textHash - text[i] * h) + text[i +
pattSize]) % q;

            //when hash value is negative, make it positive
            if (textHash < 0)
                textHash += q;
        }
    }
}

int main()
{
    int sizeText, sizePattern;
    char temp, temp1;
    vector<char> text;
    vector<char> pattern;
    int q;

    cout << "Enter Size of Text: ";
    cin >> sizeText;
```

```
    cout << "\nEnter Text: ";
    for (int i = 0; i < sizeText; i++)
    {
        cin >> temp;
        text.push_back(temp);
    }

    cout << "\nEnter Size of Pattern: ";
    cin >> sizePattern;

    cout << "\nEnter Pattern: ";
    for (int i = 0; i < sizePattern; i++)
    {
        cin >> temp1;
        pattern.push_back(temp1);
    }

    cout << "\nEnter value of q: ";
    cin >> q;

    rabinKarp(text, pattern, q);
    return 0;
}
```

Output:

```
Enter Size of Text: 19

Enter Text: 2359023141526739921

Enter Size of Pattern: 5

Enter Pattern: 31415

Enter value of q: 13
--------------------------------

Pattern found at index: 6

--------------------------------
Process exited after 44.95 seconds with return value 0
Press any key to continue . . .
```

```
Enter Size of Text: 19

Enter Text: 2359023141526739921

Enter Size of Pattern: 5

Enter Pattern: 31415

Enter value of q: 11
--------------------------------

Pattern found at index: 6

--------------------------------
Process exited after 22.87 seconds with return value 0
Press any key to continue . . .
```

```
Enter Size of Text: 21

Enter Text: ABAAABCDBBABCDDEBCABC

Enter Size of Pattern: 3

Enter Pattern: ABC

Enter value of q: 101
--------------------------------

Pattern found at index: 4

Pattern found at index: 10

Pattern found at index: 18

--------------------------------
Process exited after 24.6 seconds with return value 0
Press any key to continue . . .
```

Conclusion:

In this Practical we performed String Matching algorithm known as Rabin Karp Algorithm. And found out that the time complexity of this particular algorithm is O(m+n) and in worst case it is O(m*n)

[8.3]

Aim: Boyers Moore Algorithm

Theory:

The Boyer Moore algorithm is a searching algorithm in which a string of length **n** and a pattern of length **m** is searched. It prints all the occurrences of the pattern in the Text.
Like the other string matching algorithms, this algorithm also preprocesses the pattern.
Boyer Moore uses a combination of two approaches – Bad character and good character heuristic. Each of them is used independently to search the pattern.
In this algorithm, different arrays are formed for both heuristics by pattern processing, and the best heuristic is used at each step. Boyer Moore starts to match the pattern from the last, which is a different approach from KMP and Naive.

Let us now understand the bad character heuristic :

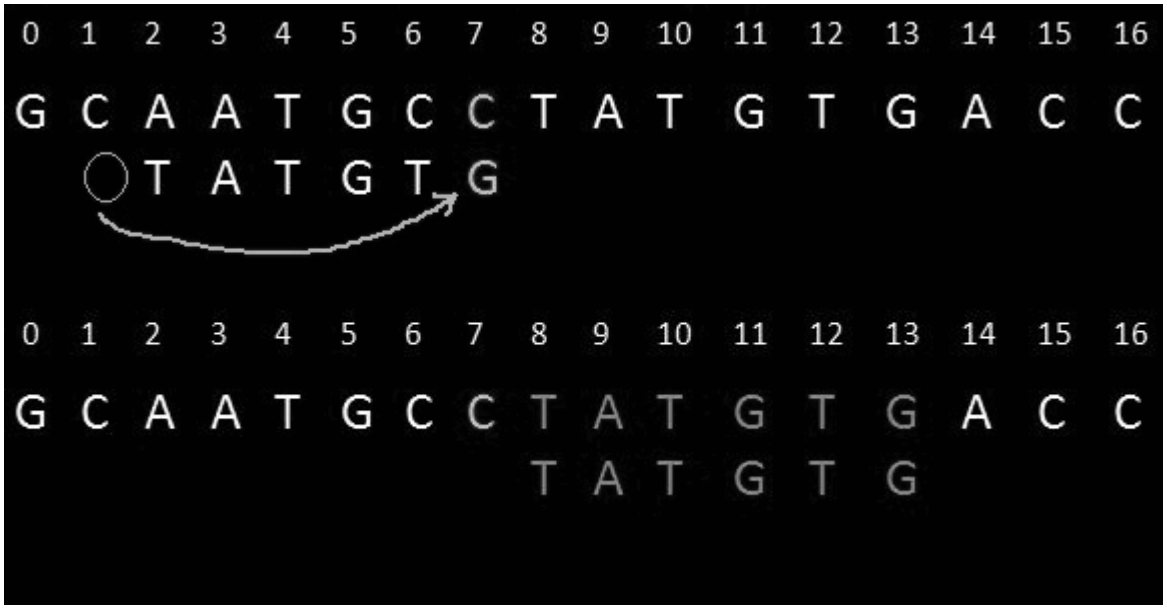
Bad character: A character in the Text that has no match with the pattern is called a bad character.
Now, when there is a case of mismatch, we shift the pattern until it becomes a match, and the pattern moves past the mismatched character.

MISMATCH BECOMES A MATCH
Find the position of the last character that mismatched in the pattern and, then shift the pattern until it gets aligned to the mismatched character in the Text.

Example: In the above Text, there is a mismatch at position 3(A does not match with G). Now we find the last occurrence of A in our Text. At position 1, We get the A now we shift the pattern to position 1.

PATTERN MOVE PAST THE MISMATCH CHARACTER

We look up the last occurrence of the character that does not match the pattern; if it does not exist in the pattern, we move the pattern past that last mismatched character.



Algorithm:

naiveAlgorithm(mainString, pattern)

M = [ ]

for s = 0 to n − m

valid = TRUE

for j = 0 to m − 1

if P[j] = ∗ and P[j] = S[s + j]

valid = FALSE

if valid

M.APPEND(s); return M

Code:

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

void fullSuffixMatch(int shiftArr[], int borderArr[], string pattern) {
   int n = pattern.size();       //find length of pattern
   int i = n;
   int j = n+1;
   borderArr[i] = j;

   while(i > 0) {
      //search right when (i-1)th and (j-1)th item are not same
      while(j <= n && pattern[i-1] != pattern[j-1] ) {
         if(shiftArr[j] == 0)
            shiftArr[j] = j-i;     //shift pattern from i to j
         j = borderArr[j];       //update border
      }
      i--;
      j--;
      borderArr[i] = j;
   }
}

void partialSuffixMatch(int shiftArr[], int borderArr[], string pattern) {
   int n = pattern.size();    //find length of pattern
   int j;
   j = borderArr[0];

   for(int i = 0; i<n; i++) {
      if(shiftArr[i] == 0)
         shiftArr[i] = j;        //when shift is 0, set shift to border value
         if(i == j)
            j = borderArr[j];    //update border value
   }
}

void searchPattern(string mainString, string pattern, int array[], int *index)
{
   int patLen = pattern.size();
   int strLen = mainString.size();
   int borderArray[patLen+1];
   int shiftArray[patLen + 1];

   for(int i = 0; i<=patLen; i++) {
      shiftArray[i] = 0;     //set all shift array to 0
   }

   fullSuffixMatch(shiftArray, borderArray, pattern);
```

```
   partialSuffixMatch(shiftArray, borderArray, pattern);
   int shift = 0;

   while(shift <= (strLen - patLen)) {
      int j = patLen - 1;
      while(j >= 0 && pattern[j] == mainString[shift+j]) {
         j--;          //reduce j when pattern and main string character is
matching
      }

      if(j < 0) {
         (*index)++;
         array[(*index)] = shift;
         shift += shiftArray[0];
      }else {
          shift += shiftArray[j+1];
      }
   }
}

int main() {

   cout<<"Boyer's Moore Algorithm\n";

   string mainString;
   cout<<"Enter Main String : ";
   cin>>mainString;

   string pattern;
   cout<<"Enter Pattern String : ";
   cin>>pattern;

   int locArray[mainString.size()];
   int index = -1;
   searchPattern(mainString, pattern, locArray, &index);

   for(int i = 0; i <= index; i++) {
      cout << "Pattern found at position: " << locArray[i]<<endl;
    }
}
```

Output:

```
Boyer's Moore Algorithm
Enter Main String : ABACABCABACBACA
Enter Pattern String : ACA
Pattern found at position: 2
Pattern found at position: 12

--------------------------------
Process exited after 10.47 seconds with return value 0
Press any key to continue . . .
```

Conclusion:

In this practical we performed Boyers Moore Algorithm and found out that the time complexity of this particular algorithm is O(m*n) which is the worst-case complexity of String-Matching Algorithm.

[8.4]

Aim: KMP Algorithm.

Theory:

The KMP algorithm is a solution to the string search problem wherein we are required to find if a given pattern string occurs in another main string. It is one of the advanced string matching algorithm that was conceived by Donald Knuth, James H. Morris and Vaughan Pratt, hence the name **"KMP algorithm"**.

The algorithm **keeps a track of the comparison of characters between main text and pattern**, thereby ensuring that comparisons that have already been done are not repeated, i.e. backtracking of the main string never occurs. All this results in a linear matching time and a more optimized solution.

Algorithm:

COMPUTE- PREFIX- FUNCTION (P)

1. m ←length [P] //'p' pattern to be matched
2. Π [1] ← 0
3. k ← 0
4. for q ← 2 to m
5. do while k > 0 and P [k + 1] ≠ P [q]
6. do k ← Π [k]
7. If P [k + 1] = P [q]
8. then k← k + 1
9. Π [q] ← k
10. Return Π

KMP-MATCHER (T, P)

1. n ← length [T]
2. m ← length [P]
3. Π← COMPUTE-PREFIX-FUNCTION (P)
4. q ← 0 // numbers of characters matched
5. for i ← 1 to n // scan S from left to right
6. do while q > 0 and P [q + 1] ≠ T [i]
7. do q ← Π [q] // next character does not match
8. If P [q + 1] = T [i]
9. then q ← q + 1 // next character matches
10. If q = m // is all of p matched?
11. then print "Pattern occurs with shift" i - m
12. q ← Π [q] // look for the next match

Code:

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

void computePrefix(string p, int m, int lps[])
{
    // length of the previous longest prefix suffix
    int l = 0;

    lps[0] = 0; // lps[0] is always 0

    //calculating lps[i] for i = 1 to M-1
    int i = 1;
    while (i < m) {
        if (p[i] == p[l]) {
            l++;
            lps[i] = l;
            i++;
        }
        else
        {
                if (l != 0) {
                l = lps[l - 1];

            }
            else
            {
                lps[i] = 0;
                i++;
            }
        }
    }
}

void kmpPatternSearch(string p, string S)
{
    int m = p.length();
    int n = S.length();

    // creating lps array
    int lps[m];

    // finding prefix table
    computePrefix(p, m, lps);

    int i = 0;
    int j = 0;
    while (i < n) {
```

```
        if (p[j] == S[i]) {
            j++;
            i++;
        }

        if (j == m) {
            cout<<"Pattern found at location: "<<i - j<<"\n";
            j = lps[j - 1];
        }

        // mismatch case
        else if (i < n && p[j] != S[i]) {
            // Skip matching lps[0..lps[j-1]] characters
            if (j != 0)
                j = lps[j - 1];
            else
                i = i + 1;
        }
    }
}

int main() {
    cout<<"KMP Algorithm\n";

    string text;
    cout<<"Enter Main String : ";
    cin>>text;

    string pat;
    cout<<"Enter Pattern String : ";
    cin>>pat;
    kmpPatternSearch(pat, text);
    return 0;
}
```

Output:

```
KMP Algorithm
Enter Main String : ABACABCABACBACA
Enter Pattern String : ACA
Pattern found at location: 2
Pattern found at location: 12

--------------------------------
Process exited after 20.89 seconds with return value 0
Press any key to continue . . .
```

Conclusion:

In this practical we performed KMP Algorithm and found out that the worst case time complexity of this particular algorithm is O(n).