Rabin Karp Algorithm

Tuesday, November 23, 2021 12:48 AM

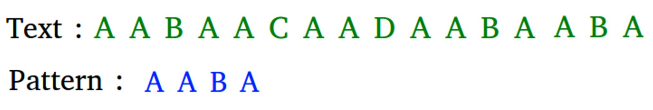
Rabin-Karp Algorithm for Pattern Searching

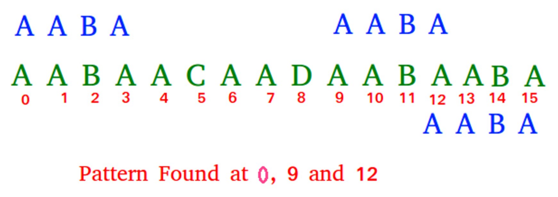
- Difficulty Level : Medium
- Last Updated : 20 Oct, 2021

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

Examples:

```
Input:  txt[] = "THIS IS A TEST TEXT"
        pat[] = "TEST"
Output: Pattern found at index 10
Input:  txt[] =  "AABAACAADAABAABA"
        pat[] =  "AABA"
Output: Pattern found at index 0
        Pattern found at index 9
        Pattern found at index 12
```





The Naive String Matching algorithm slides the pattern one by one. After each slide, it one by one checks characters at the current shift and if all characters match then prints the match.

Like the Naive Algorithm, Rabin-Karp algorithm also slides the pattern one by one. But unlike the Naive algorithm, Rabin Karp algorithm matches the hash value of the pattern with the hash value of current substring of text, and if the hash values match then only it starts matching individual characters. So Rabin Karp algorithm needs to calculate hash values for following strings.

1) Pattern itself.

2) All the substrings of the 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 the following property.

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

The hash function suggested by Rabin and Karp calculates an integer value. The integer value for a string is the numeric value of a string.

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

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

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

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

d: Number of characters in the alphabet

q: A prime number

h: d^(m-1)

How does the above expression work?

This is simple mathematics, we compute decimal value of current window from previous window.

For example pattern length is 3 and string is “23456”

You compute the value of first window (which is “234”) as 234.

How how will you compute value of next window “345”? You will do (234 – 2*100)*10 + 5 and get 345.

From <https://www.geeksforgeeks.org/rabin-karp-algorithm-for-pattern-searching/>

```java
// Following program is a Java implementation
// of Rabin Karp Algorithm given in the CLRS book

public class Main
{
    // d is the number of characters in the input alphabet
    public final static int d = 256;

    /* pat -> pattern
        txt -> text
        q -> A prime number
    */
    static void search(String pat, String txt, int q)
    {
        int M = pat.length();
        int N = txt.length();
        int i, j;
        int p = 0; // hash value for pattern
        int t = 0; // hash value for txt
        int h = 1;

        // The value of h would be "pow(d, M-1)%q"
        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.charAt(i))%q;
            t = (d*t + txt.charAt(i))%q;
        }

        // Slide the pattern over text one by one
        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 )
            {
                /* Check for characters one by one */
                for (j = 0; j < M; j++)
                {
                    if (txt.charAt(i+j) != pat.charAt(j))
                        break;
             }

                // if p == t and pat[0...M-1] = txt[i, i+1, ...i+M-1]
                if (j == M)
                    System.out.println("Pattern found at index " + i);
            }

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

                // We might get negative value of t, converting it
                // to positive
                if (t < 0)
                t = (t + q);
            }
        }
    }

    /* Driver Code */
    public static void main(String[] args)
    {
        String txt = "GEEKS FOR GEEKS";
        String pat = "GEEK";

          // A prime number
        int q = 101;

          // Function Call
        search(pat, txt, q);
    }
}

// This code is contributed by nuclode
```

Output:

```
Pattern found at index 0
Pattern found at index 10
```

Time Complexity:

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

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