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Experiment 13:

- **AIM:** **To study and implement Rabin-Karp Algorithm for Pattern Searching.**

- **THEORY:**

The Rabin-Karp string matching algorithm calculates a hash value for the pattern, as well as for each M-character subsequences of text to be compared. If the hash values are unequal, the algorithm will determine the hash value for next M-character sequence. If the hash values are equal, the algorithm will analyze the pattern and the M-character sequence. In this way, there is only one comparison per text subsequence, and character matching is only required when the hash values match.

RABIN-KARP-MATCHER (T, P, d, q)

1. $n \leftarrow$ length [T]
2. $m \leftarrow$ length [P]
3. $h \leftarrow d^{m-1} \bmod q$
4. $p \leftarrow 0$
5. $t_0 \leftarrow 0$
6. for $i \leftarrow 1$ to m
7. do $p \leftarrow (dp + P[i]) \bmod q$
8. $t_0 \leftarrow (dt_0 + T[i]) \bmod q$
9. for $s \leftarrow 0$ to $n-m$
10. do if $p = t_s$
11. then if P [1.....m] = T [s+1.....s + m]
12. then "Pattern occurs with shift" s
13. If $s < n-m$
14. then $t_{s+1} \leftarrow (d(t_s - T[s+1]h) + T[s+m+1]) \bmod q$

Example: For string matching, working module q = 11, how many spurious hits does the Rabin-Karp matcher encounters in Text T = 31415926535.......

T = 31415926535.......

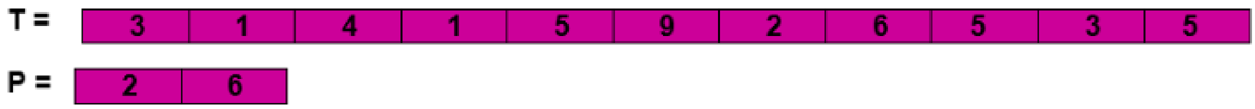
P = 26

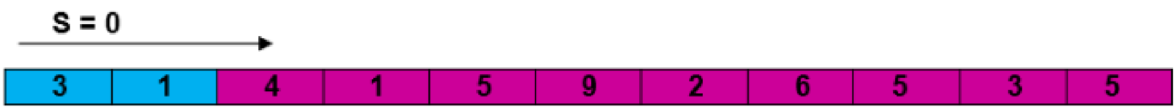
Here T.Length =11 so Q = 11

And P mod Q = 26 mod 11 = 4

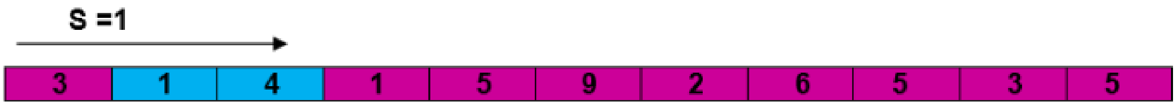
Now find the exact match of P mod Q...

Solution:

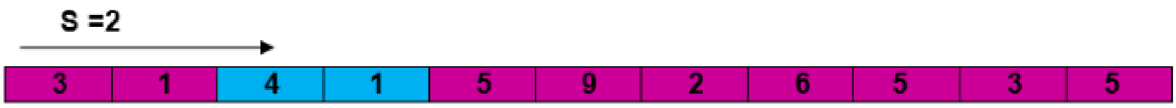




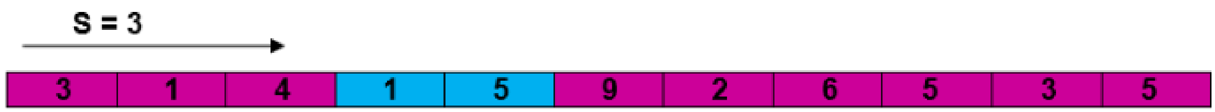
31 mod 11 = 9 not equal to 4



14 mod 11 = 3 not equal to 4



41 mod 11 = 8 not equal to 4



15 mod 11 = 4 equal to 4 SPURIOUS HIT

S = 4

3	1	4	1	5	9	2	6	5	3	5

59 mod 11 = 4 equal to 4 SPURIOUS HIT

S = 5

3	1	4	1	5	9	2	6	5	3	5

92 mod 11 = 4 equal to 4 SPURIOUS HIT

S = 6

3	1	4	1	5	9	2	6	5	3	5

26 mod 11 = 4 EXACT MATCH

S = 7

3	1	4	1	5	9	2	6	5	3	5

S = 7

3	1	4	1	5	9	2	6	5	3	5

65 mod 11 = 10 not equal to 4

S = 8

3	1	4	1	5	9	2	6	5	3	5

53 mod 11 = 9 not equal to 4

S = 9

3	1	4	1	5	9	2	6	5	3	5

35 mod 11 = 2 not equal to 4

The Pattern occurs with shift 6.

Complexity:

The running time of **RABIN-KARP-MATCHER** in the worst case scenario **O ((n-m+1) m** but it has a good average case running time. If the expected number of strong shifts is small **O (1)** and prime q is chosen to be quite large, then the Rabin-Karp algorithm can be expected to run in time **O (n+m)** plus the time to require to process spurious hits.

Given a text T**[0. . .n-1]** and a pattern P**[0. . .m-1]**, write a function search(char P[], char T[]) that prints all occurrences of P[] present in T[] using Rabin Karp algorithm. You may assume that **n > m**.

Examples:

Input: *T[] = "THIS IS A TEST TEXT", P[] = "TEST"*
Output: *Pattern found at index 10*

Input: *T[] = "AABAACAADAABAABA", P[] = "AABA"*
Output: *Pattern found at index 0*
Pattern found at index 9
Pattern found at index 12

How is Hash Value calculated in Rabin-Karp?

Hash value is used to efficiently check for potential matches between a **pattern** and substrings of a larger **text**. The hash value is calculated using a **rolling hash function**, which allows you to update the hash value for a new substring by efficiently removing the contribution of the old character and adding the contribution of the new character. This makes it possible to slide the pattern over the **text** and calculate the hash value for each substring without recalculating the entire hash from scratch.

Here's how the hash value is typically calculated in Rabin-Karp:

Step 1: Choose a suitable **base** and a **modulus**:

- Select a prime number '**p**' as the modulus. This choice helps avoid overflow issues and ensures a good distribution of hash values.
- Choose a base '**b**' (usually a prime number as well), which is often the size of the character set (e.g., 256 for ASCII characters).

Step 2: Initialize the hash value:

- Set an initial hash value '**hash**' to **0**.

Step 3: Calculate the initial hash value for the **pattern**:

- Iterate over each character in the **pattern** from **left** to **right**.
- For each character **'c'** at position **'i'**, calculate its contribution to the hash value as **'c * (bpattern_length – i – 1) % p'** and add it to '**hash**'.
- This gives you the hash value for the entire **pattern**.

Step 4: Slide the pattern over the **text**:

- Start by calculating the hash value for the first substring of the **text** that is the same length as the **pattern**.

Step 5: Update the hash value for each subsequent substring:

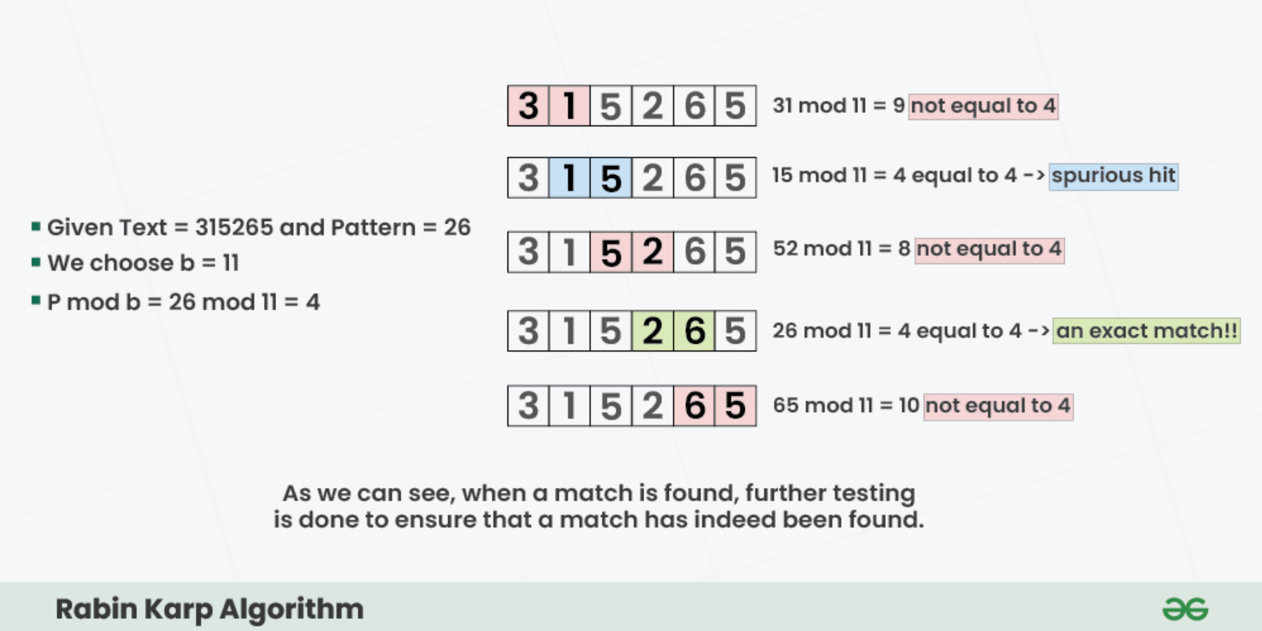
- To slide the **pattern** one position to the right, you remove the contribution of the leftmost character and add the contribution of the new character on the right.
- The formula for updating the hash value when moving from position **'i'** to **'i+1'** is:

```
hash = (hash - (text[i - pattern_length] * (b^(pattern_length - 1)) % p) * b +
text[i]
```

Step 6: Compare hash values:

- When the hash value of a substring in the **text** matches the hash value of the **pattern**, it's a **potential match**.
- If the hash values match, we should perform a character-by-character comparison to confirm the match, as hash collisions can occur.

Below is the Illustration of above algorithm:



Step-by-step approach:

- Initially calculate the hash value of the pattern.
- Start iterating from the starting of the string:
    - Calculate the hash value of the current substring having length **m**.
    - If the hash value of the current substring and the pattern are same check if the substring is same as the pattern.
    - If they are same, store the starting index as a valid answer. Otherwise, continue for the next substrings.
- Return the starting indices as the required answer.

➢ <u>C PROGRAM:</u>

```
#include <stdio.h>

#include <string.h>


#define d 256


void search(char pat[], char txt[], int q)

{

    int M = strlen(pat);

    int N = strlen(txt);
```

```
int i, j;
int p = 0;
int t = 0;
int h = 1;

for (i = 0; i < M - 1; i++)
    h = (h * d) % q;

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++) {
    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);
    }

    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];
    char pat[100];
    int q;

    printf("------------- RABIN-KARP ALGORITHM -------------\n\n");

    printf("Enter the text: ");
    scanf("%s", txt);

    printf("Enter the pattern: ");
    scanf("%s", pat);

    printf("Enter a prime number: ");
    scanf("%d", &q);

    search(pat, txt, q);
    return 0;
}
```

- **<u>OUTPUT:</u>**

```
------------- RABIN-KARP ALGORITHM -------------

Enter the text: Hello
Enter the pattern: lo
Enter a prime number: 13
Pattern found at index 3


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

```
------------- RABIN-KARP ALGORITHM -------------

Enter the text: ABRAHBGFSDABRG
Enter the pattern: ABR
Enter a prime number: 101
Pattern found at index 0
Pattern found at index 10


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

- **<u>CONCLUSION:</u> Hence, we have successfully implemented Rabin-Karp Algorithm for Pattern Searching; LO 1, LO 2.**