

# Tries

Data and File Structures Laboratory

<http://www.isical.ac.in/~dfslab/2019/index.html>

## Problem

Determine whether there are any duplicates in a given list of  $N$  binary strings (i.e., strings consisting of 0s and 1s only). Note that the strings are too long to be stored as integers.

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Repeat the above problem, but assume that the strings consist of 0s, 1s and 2s only.

# Implementation

```
#define NUM_SYMS 26

typedef unsigned int TRIE_NODE[NUM_SYMS + 1];

unsigned int max_nodes, num_nodes;
TRIE_NODE *trie;
```

The last field stores how many times this string has occurred as a complete word.

`trie, num_nodes, max_nodes` are global variables in the following code.

# Implementation: init\_trie

```
int init_trie()
{
    max_nodes = 10000;
    if (NULL == (trie = (TRIE_NODE *) calloc(max_nodes, sizeof(TRIE_NODE))))
        ERR_MESG("init-trie: out of memory\n");
    num_nodes = 1;
    return 0;
}
```

# Implementation: insert\_node

```
int insert_node()
{
    if (num_nodes == max_nodes) {
        max_nodes *= 2;
        if (NULL == (trie = Realloc(trie, max_nodes, TRIE_NODE)))
            ERR_MESG("insert-node: out of memory\n");
        bzero((void *) (trie + num_nodes), num_nodes * sizeof(TRIE_NODE));
    }
    num_nodes++;
    return num_nodes - 1;
}
```

# Implementation: insert\_string |

```
int insert_string(char *s)
{
    unsigned int index = 0;
    int c, new_index;

    while (*s) {
        c = *s;
        if (c >= 'A' && c <= 'Z')
            c = 'a' + c - 'A';
        if (c >= 'a' && c <= 'z') {
            c = c - 'a';
            if (trie[index][c] != 0)
                /* just follow the pointer */
                index = trie[index][c];
            else {
```

# Implementation: insert\_string II

```
        /* need new node */
        if (UNDEF == (new_index = insert_node()))
            return UNDEF;
        index = trie[index][c] = new_index;
    }
}
else
    fprintf(stderr, "Unexpected character %d\n",
c);
    s++;
}
trie[index][NUM_SYMS]++;

return 0;
}
```



# Other trie operations

- Searching: similar to insertion
- Deletion: find the leaf node corresponding to the string, and set value (e.g., frequency) to NULL / 0
- Enumeration: similar to pre-order traversal

- Search hit: linear in length of string
- Search miss: usually sub-linear
- Space: depends on whether many strings share a common prefix

- For tries that don't change (e.g., dictionaries)

```
1  if (NULL == (fp = fopen("dict.h", "w")))
2      ERR_MSG("make-dict: error opening output file\n");
3  fprintf(fp, "#include \"trie.h\"\n\nTRIE_NODE dict[] = {\n");
4  for (i = 0; i < num_nodes; i++) {
5      fprintf(fp, "    { ");
6      for (j = 0; j < NUM_SYMS + 1; j++)
7          fprintf(fp, "%u, ", trie[i][j]);
8      fprintf(fp, "},\n");
9  }
10 fprintf(fp, "};\n");
11 fclose(fp);
```

# Persistent tries

```
#include "trie.h"
```

```
TRIE_NODE dict[] = {  
    { 1, 2695, 5429, 8565, 10135, 11370, 12397, 14016, 15784, 16439, 17334,  
      18692, 20363, 23617, 24742, 25516, 27617, 27774, 29282, 32524, 34362,  
      34671, 35389, 36448, 36548, 36892, 0, },  
    { 3, 5, 9, 221, 336, 387, 426, 496, 14, 549, 553, 582, 19, 1261, 21, 1666,  
      1764, 1795, 2, 30, 2423, 2573, 35, 2624, 2627, 39, 2, },  
    { 2153, 43985, 24, 0, 44065, 0, 2162, 2166, 2218, 0, 44114, 28, 2230, 0,  
      2234, 2237, 2251, 0, 2256, 2276, 2309, 0, 2315, 0, 44635, 0, 3, },  
    { 0, 0, 43, 0, 0, 0, 0, 0, 0, 0, 0, 47, 0, 0, 0, 0, 0, 53, 4, 0, 0, 0, 0,  
      0, 0, 0, 0, },  
    { 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,  
      0, 0, 1, },  
    ...  
}
```

# What if the alphabet is large?

```
typedef struct {  
    AVL_TREE alphabet;  
    int count;  
} TRIE_NODE;
```

```
typedef struct {  
    unsigned long max_nodes, num_nodes;  
    TRIE_NODE *trie;  
} TRIEPP;
```

1. Given a sequence of characters  $a_1a_2 \dots a_N$ , a character  $n$ -gram is defined as any sequence  $a_i a_{i+1} a_{i+2} \dots a_{i+n-1}$  where  $n > 0$  and  $1 \leq i \leq M - n + 1$ . Write a program to find the frequency of the most frequent  $n$ -gram in a given text that consists *only of lower case letters*. The value of  $n$  and the text will be given to you as inputs. You may assume that the input consists of lower case letters, blanks and newlines only.
2. Given a pair of integers  $X = (X_0 X_1 \dots X_n)$  and  $Y = (Y_0 Y_1 \dots Y_n)$  in base 10, we define the XOR of  $X$  and  $Y$  as  $X \oplus Y = (Z_0 Z_1 \dots Z_n)$ , where  $Z_i = (X_i + Y_i) \bmod 10$ . Write a program that will take an array of  $n$ -digit integers in base 10 and return the maximum integer that can be obtained by XOR-ing exactly  $k$  numbers. Consider  $n$  and  $k$  as user inputs.