Computing Laboratory

Tries

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Motivation

Problem I

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

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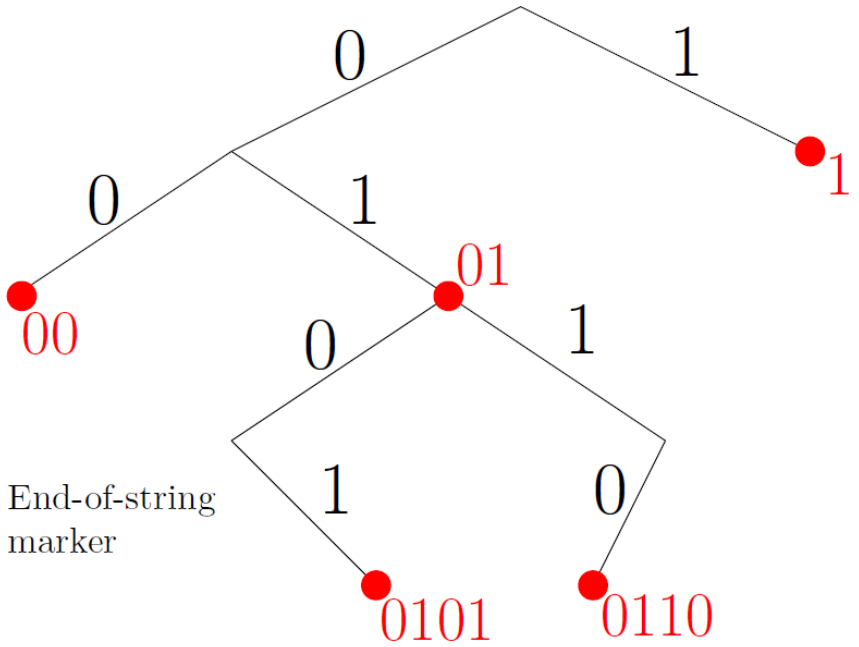

Motivation (contd.)

Problem II

Determine whether there are any duplicates in a given list of N English strings (i.e., strings consisting of characters from **a-z** only).

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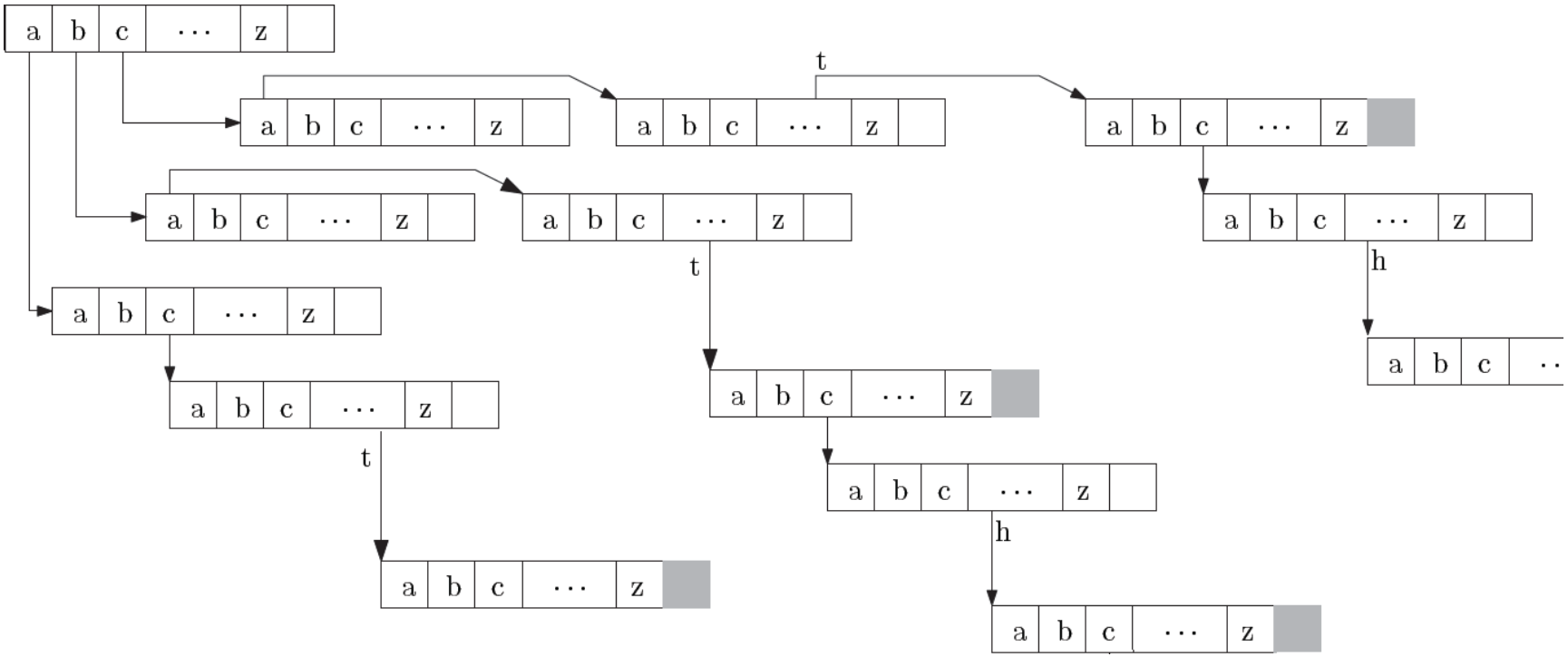

Tries – implementation

- Trie $\equiv$ array of trie nodes
- Each node is an array
  - indexed by symbols
  - array values correspond to indices of child nodes

	a	b	...	y	z	flag
0						
1						
⋮			⋮			

Implementation

```
#define NUM_SYMS 26

/* The additional field stores how many times this
string has occurred as a complete word */
typedef unsigned int TRIE_NODE[NUM_SYMS + 1];

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

Note: `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{
                /* need new node */
                if(UNDEF == (new_index = insert_node()))
                    return UNDEF;
                index = trie[index][c] = new_index;
            }
        }
```

Implementation: insert_string (contd.)

```
            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

Trie performance

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

Persistent tries

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

```
if(NULL == (fp = fopen("dict.h", "w")))
    ERR_MESG("make-dict: error opening output file\n");
fprintf(fp, "#include \"trie.h\"\n\nTRIE_NODE dict[] = {\n");
for(i = 0; i < num_nodes; i++){
    fprintf(fp, "    { ");
    for (j = 0; j < NUM_SYMS + 1; j++)
        fprintf(fp, "%u, ", trie[i][j]);
    fprintf(fp, "},\n");
}
fprintf(fp,"};\n");
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, 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;
```

Problems – Day 18

1. Given a sequence of characters $a_1 a_2 \ldots a_M$, a character n-gram is defined as any sequence $a_i a_{i+1} a_{i+2} \ldots a_{i+n-1}$ 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 $X = (X_0 X_1 \ldots X_n)$ and $Y = (Y_0 Y_1 \ldots Y_n)$ in base 10, we define the `XOR` of X and Y as $X \oplus Y = (Z_0 Z_1 \ldots Z_n)$, where $Z_i = (X_i + Y_i) \mod 10$. 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.

Problems – Day 18

3. Given a list of unique alphanumeric strings, say STR, write a program to find out all the pairs of the distinct indices (i, j) in the given list, so that the concatenation of the two strings $\texttt{STR}[i] + \texttt{STR}[j]$ is a palindrome.