Tries

Computing Lab

http://www.isical.ac.in/~dfslab

Motivation

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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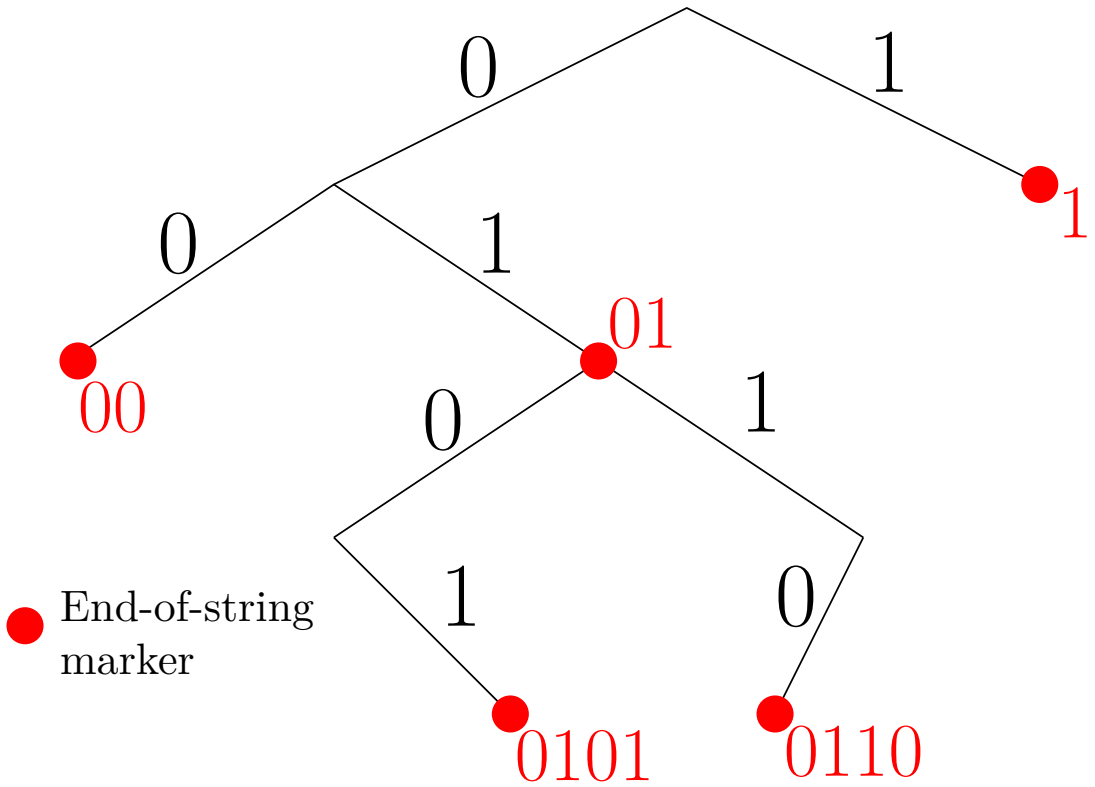
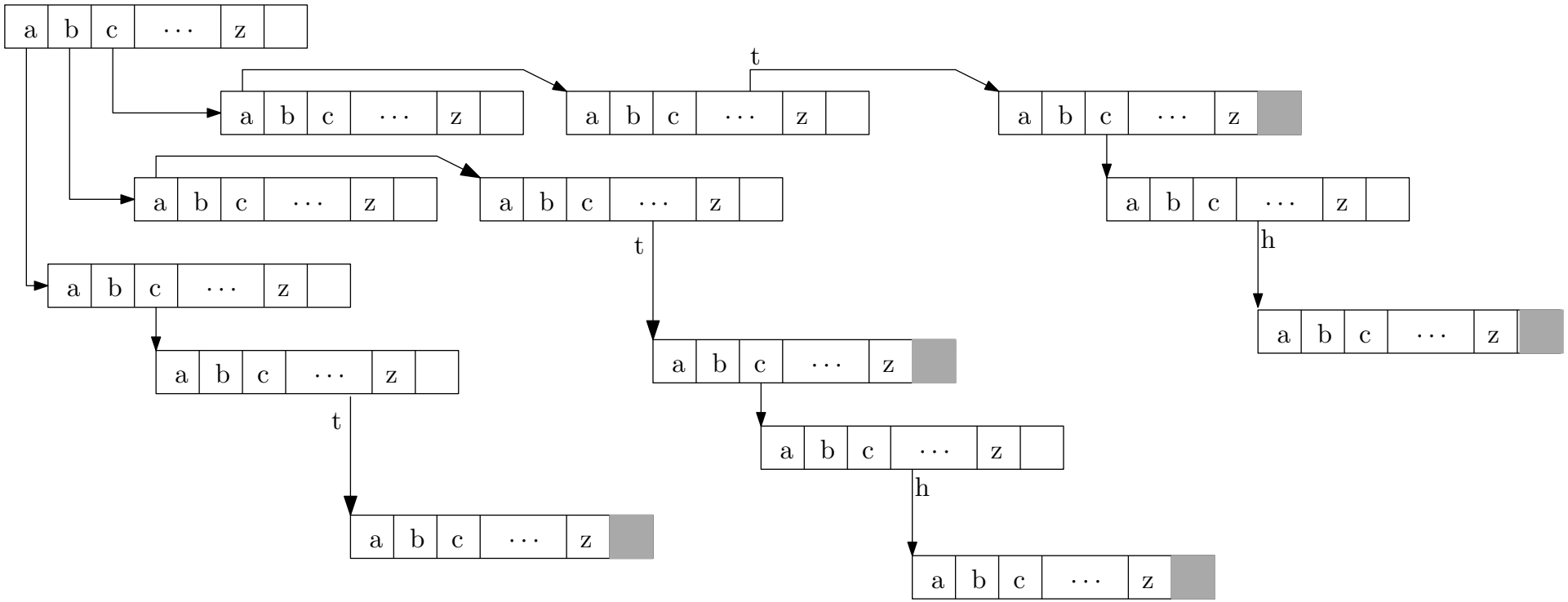


Motivation (contd.)

Problem

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

Trie



Tries – implementation I

- 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

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 I

```
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;
```

Implementation: `insert_string` II

```
                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

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, 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;
```

Tries – C-like implementation I

- As in C
  - trie is an 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						
⋮			⋮			

Tries – C-like implementation II

```
if __name__ == '__main__': # can use code in this file via import (?)
    if len(sys.argv) != 2 : # == argc
        # Note the printf-like syntax below
        sys.exit('Usage: %s <dict file name>' % sys.argv[0])

    # CAUTION:
    # trie = [ [ 0 ] * (NUM_SYMBOLS+1) ] * INIT_SIZE WILL NOT WORK
    # The above creates copies of the SAME list, so when you modify
    # one of them they all change.
    # See https://stackoverflow.com/questions/6667201/how-to-define-a-
    two-dimensional-array-in-python
    trie = [ [ 0 ] * (NUM_SYMBOLS+1) for i in range(INIT_SIZE) ]

    with open(sys.argv[1]) as f : # with => don't need a f.close()
        for line in f: # ASSUMPTION: one word per line
            insert_string(trie, line.strip())
```

Tries – C-like implementation III

```
def insert_string(trie, s) :
    index = 0
    for c in s.lower() :
        i = ord(c) - ord('a')    # get ASCII value
        if i < 0 or i >= NUM_SYMBOLS :
            # print("Unexpected character %c in string %s" % (c, s))
            continue
        if trie[index][i] == 0 : # need new node
            new_index = get_new_node(trie)
            trie[index][i] = new_index
            index = new_index
        else :
            index = trie[index][i]
    trie[index][NUM_SYMBOLS] += 1
```

Tries – C-like implementation IV

```
def get_new_node(trie) :
    global num_nodes, max_nodes
    if num_nodes == max_nodes :
        trie.extend([ [ 0 ] * (NUM_SYMBOLS+1) for i in range(INIT_SIZE)
    ])
        max_nodes += INIT_SIZE
    num_nodes += 1
    return num_nodes - 1
```

Tries++

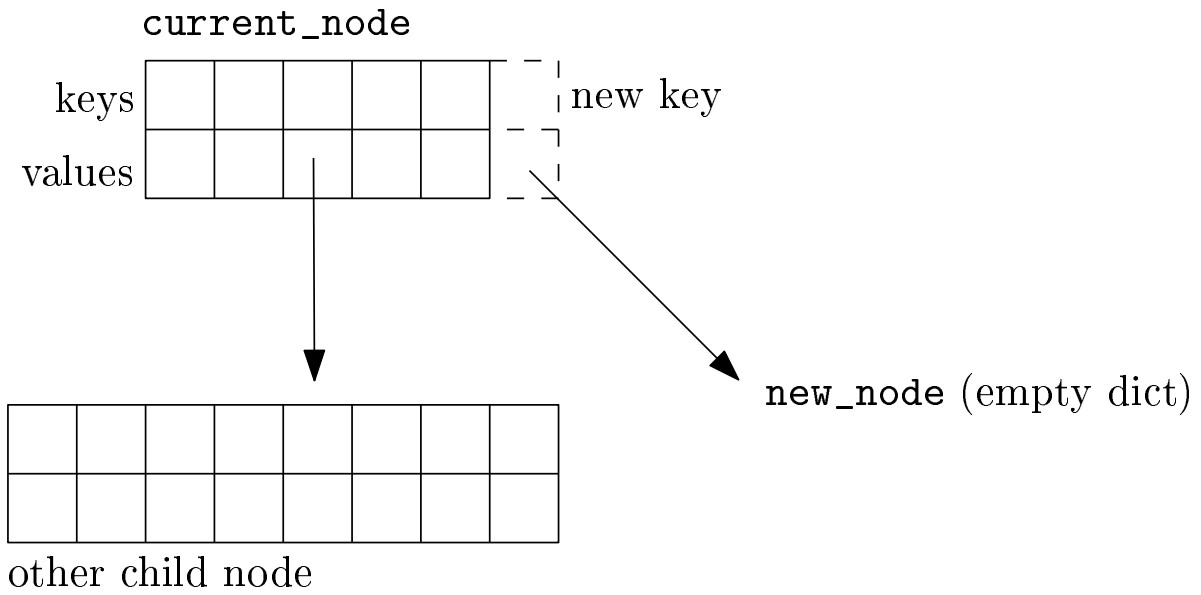
- Each trie node is a dictionary (list of key, value pairs)
- Keys in each dictionary: symbols in your alphabet
- Value for any key: reference (pointer) to child node (another dictionary)

Initialisation

```
trie = { } # Just the first node
```

Tries++ – Insertion

```
def insert_string(trie, s) :
    current_node = trie
    for c in s.lower() :
        if c not in current_node : # c is not a key in this dictionary
            new_node = {}
            current_node[c] = new_node
            current_node = new_node
        else :
            current_node = current_node[c]
```



Tries++ – Searching

```
def search(trie, s) :
    current_node = trie
    for c in s.lower() :
        if c not in current_node :
            return False
        else :
            current_node = current_node[c]
```

```
    while True:
        s = input("Enter word to search for: ")
        if s == "quit" : # Why can you not use "is" ?
            break
        if search(unpickled_trie, s) :
            print("Word found")
        else :
            print("Word not found")
```

Exercise

1. Given a sequence of **non-whitespace** 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.