Prefix Tree/Trie

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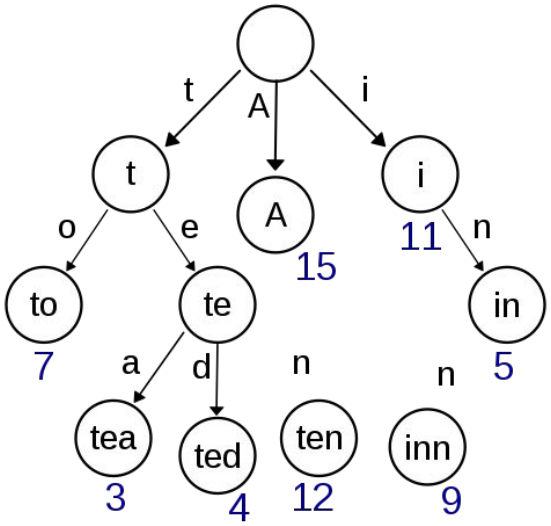
Definition

In computer science, a **trie**, also called **digital tree** or **prefix tree**, is a type of search tree, a tree data structure used for locating specific keys from within a set.

A trie for keys "A", "to", "tea", "ted", "ten", "i", "in", and "inn". Each complete English word has an arbitrary integer value associated with it.



208. Implement Trie

```python
class TrieNode:
    def __init__(self):
        self.word = False
        self.children = {}

class Trie: #  prefix tree(字典🎄)
    def __init__(self):
        """
        Initialize your data structure here.
        """
        self.root = TrieNode()

    def insert(self, word):
        """
        Inserts a word into the trie.
        :type word: str
        :rtype: void
        """
        node = self.root
        for ch in word:
            if ch not in node.children:
                node.children[ch] = TrieNode()
            node = node.children[ch] # move on to the nxt level
        node.word = True # loop to the end, store the word as true
```

```python
    def search(self, word):
        """
        Returns if the word is in the trie.
        :type word: str
        :rtype: bool
        """
        node = self.root
        for ch in word:
            if ch not in node.children:
                return False # go down the tree
            node = node.children[ch]
        return node.word

    def startsWith(self, prefix):
        """
        Returns if there is any word in the trie that starts with the gi
        :type prefix: str
        :rtype: bool
        """
        node = self.root
        for ch in prefix:
            if ch not in node.children:
                return False # go down the tree
            node = node.children[ch]
        return True # loop to the end and all good!
```

211. Design Add and Search Words Data Structure

```python
class WordDictionary:

    def __init__(self):
        """
        Initialize your data structure here.
        """
        self.root = TrieNode()

    def addWord(self, word: str) -> None:
        node = self.root
        for ch in word:
            if ch not in node.children:
                node.children[ch] = TrieNode()
            node = node.children[ch] # move on to the nxt level
        node.word = True # loop to the end, store the word as true

    def search(self, word: str) -> bool:
        def dfs(node, i, word):
            if i == len(word): # base case, word till end(empty)
                return node.word
            if word[i] == '.':
                for c in node.children:
                    if dfs(node.children[c], i + 1, word):
                        return True
                return False
            else:
                if word[i] not in node.children:
                    return False
                else:
                    return dfs(node.children[word[i]], i + 1, word)
        return dfs(self.root, 0, word)
```

Design a data structure that supports adding new words and finding if a string matches any previously added string.

Implement the `WordDictionary` class:

- `WordDictionary()` Initializes the object.
- `void addWord(word)` Adds `word` to the data structure, it can be matched later.
- `bool search(word)` Returns `true` if there is any string in the data structure that matches `word` or `false` otherwise. `word` may contain dots `'.'` where dots can be matched with any letter.

Input

```
["WordDictionary","addWord","addWord","addWord","search","search","search","search"]

[[],["bad"],["dad"],["mad"],["pad"],["bad"],[".ad"],["b.."]]
```

Output

```
[null,null,null,null,false,true,true,true]
```

212. Word Search II

```python
class Solution:
    def findWords(self, board: List[List[str]], words: List[str]) -> List[s
        res, trie, m, n = [], Trie(), len(board), len(board[0])
        for word in words:
            trie.insert(word)
        for i in range(m):
            for j in range(n):
                self.dfs(board, trie.root, i, j, "", res, m, n)
        return res

    def dfs(self, board, node, x, y, path, res, m, n):
        if node.word:
            res.append(path)
            node.word = False # find a word and marked as visited
        if 0 <= x < m and 0 <= y < n:
            tmp = board[x][y]
            if tmp not in node.children:
                return
            node = node.children[tmp] # go down
            board[x][y] = '#'
            for dx, dy in [(-1, 0), (1, 0), (0, -1), (0, 1)]:
                nx, ny = x + dx, y + dy
                self.dfs(board, node, nx, ny, path + tmp, res, m, n)
            board[x][y] = tmp
```

Given an `m x n board` of characters and a list of strings `words`, return *all words on the board*.

- `m == board.length`
- `n == board[i].length`
- `1 <= m, n <= 12`
- `board[i][j]` is a lowercase English letter.
- `1 <= words.length <= 3 * 10^4`
- `1 <= words[i].length <= 10`
- `words[i]` consists of lowercase English letters.
- All the strings of `words` are unique

425. Word Square

Given a set of words (without duplicates), find all word squares you can build from them.

```
Input: ["area","lead","wall","lady","ball"]

wall

area

lead

lady
```

```python
class TrieNode:
    def __init__(self):
        self.children = defaultdict(TrieNode)
        self.isWord = False
        self.words = []

class Trie: #  prefix tree(字典🎄)
    def __init__(self, words):
        self.root = TrieNode()
        for word in words:
            self.insert(word)

    def insert(self, word):
        node = self.root
        node.words.append(word)
        for ch in word:
            node = node.children[ch] # move on to the nxt level
            node.words.append(word)
        node.isWord = True # loop to the end, store the word as true
        # node.string = word

    def allWords(self, prefix):
        # return all possible words with current prefix
        node = self.root
        for ch in prefix:
            if not node.children.get(ch, None):
                return [] # go down the tree
            node = node.children[ch]
        return node.words
```

```python
class Solution:
    def wordSquares(self, words: List[str]) -> List[List[str]]:
        res, k, trie = [], len(words[0]), Trie(words)

        def dfs(row, matrix):
            # row means last row index + 1
            if row == k:
                res.append(matrix)
                return
            prefix = ''.join(r[row] for r in matrix)
            for word in trie.allWords(prefix):
                dfs(row + 1, matrix + [word]) # pass by val

        def dfs2(row, matrix):
            # row means last row index + 1
            if row == k:
                res.append(matrix[:]) # matrix is passed by ref, need a shallow-copy
                return
            prefix = ''.join(r[row] for r in matrix)
            for word in trie.allWords(prefix):
                matrix.append(word)
                dfs(row + 1, matrix) # pass by ref
                matrix.pop()

        dfs(0, [])
        return res
```

642. Design Search Autocomplete System

```python
class AutocompleteSystem1:
    '''
    storing all the words at each node, it increases space but makes the solution around 5 times faster.
    '''

    def __init__(self, sentences: List[str], times: List[int]):
        self.trie = TrieNode()
        self.cache_count = defaultdict(int)
        self.keyword = ""
        for i, sen in enumerate(sentences):
            self._insert(sen, self.trie)
            self.cache_count[sen] = times[i]

    def _insert(self, word, trie):
        for ch in word:
            if ch not in trie.children:
                trie.children[ch] = TrieNode()
            trie = trie.children[ch]
            trie.words.append(word)
        return True

    def _search(self, word):
        trie = self.trie
        for ch in word:
            if ch not in trie.children:
                return []
            trie = trie.children[ch]
        return trie.words

    def input(self, c: str) -> List[str]:
        if c != '#':
            self.keyword += c
            sens = self._search(self.keyword)
            res = []
            for sen in sens:
                res.append((self.cache_count[sen], sen))
            res = list(set(res))
            return [sen for cnt, sen in sorted(res, key=lambda x:(-x[0], x[1]))[:3]]
        else:
            self.cache_count[self.keyword] += 1
            self._insert(self.keyword, self.trie)
            self.keyword = ""
        return []
```

Design a search autocomplete system for a search engine. Users may input a sentence (at least one word and end with a special character '#'). For each character they type except '#', you need to return the top 3 historical hot sentences that have prefix the same as the part of sentence already typed. Here are the specific rules:

Operation: AutocompleteSystem(["i love you", "island","ironman", "i love leetcode"], [5,3,2,2])

The system have already tracked down the following sentences and their corresponding times:

"i love you" : 5 times

"island" : 3 times

"ironman" : 2 times

"i love leetcode" : 2 times

676. Implement Magic Dictionary

```python
class MagicDictionary:

    def __init__(self):
        """
        Initialize your data structure here.
        """
        self.trie = Trie()

    def buildDict(self, dictionary: List[str]) -> None:
        for word in dictionary:
            self.trie.insert(word)

    def search(self, searchWord: str) -> bool:
        self.change_once_flag = False
        return self.dfs(self.trie.root, 0, searchWord)

    def dfs(self, node, pos, word):
        if pos == len(word): return node.word and self.change_once_flag
        if self.change_once_flag:
            if word[pos] in node.children:
                return self.dfs(node.children[word[pos]], pos+1, word)
            else:
                return False
        else:
            for c in node.children: # try to change in this level
                self.change_once_flag = (c != word[pos])
                if self.dfs(node.children[c], pos+1, word):
                    return True
            return False
```

`MagicDictionary()` Initializes the object.

`void buildDict(String[] dictionary)` Sets the data structure with an array of distinct strings `dictionary`.

`bool search(String searchWord)` Returns `true` if you can change exactly one character in `searchWord` to match any string in the data structure, otherwise returns `false`.

745. Prefix and Suffix Search

```python
class TrieNode():
    def __init__(self):
        self.children = {}
        self.weights = []

# create two Tries, one for prefix search,
# another one for suffix search
# then find the maximal common weight
class Trie():
    def __init__(self):
        self.root = TrieNode()

    def insert(self, word, i):
        node = self.root
        node.weights.append(i)
        for char in word:
            if char not in node.children:
                node.children[char] = TrieNode()
            node = node.children[char]
            node.weights.append(i)

    def search(self, word):
        node = self.root
        for char in word:
            if char not in node.children:
                return []
            node = node.children[char]
        return node.weights
```

- `WordFilter(string[] words)` Initializes the object with the `words` in the dictionary.
- `f(string prefix, string suffix)` Returns *the index of the word in the dictionary* which has the prefix `prefix` and the suffix `suffix`. If there is more than one valid index, return the largest of them. If there is no such word in the dictionary, return `-1`.

```python
class WordFilter1:
    def __init__(self, words: List[str]):
        self.prefix, self.suffix = Trie(), Trie()
        i, n = 0, len(words)
        while i < n:
            w = words[i]
            self.prefix.insert(w, i)
            self.suffix.insert(w[::-1], i)
            i += 1

    def f(self, prefix: str, suffix: str) -> int:
        pre = self.prefix.search(prefix)
        suf = self.suffix.search(suffix[::-1])
        i, j = len(pre) - 1, len(suf) - 1
        while i >= 0 and j >= 0:
            if pre[i] == suf[j]:
                return pre[i]
            elif pre[i] < suf[j]:
                j -= 1
            else:
                i -= 1
        return -1
```

1032. Stream of Characters

```python
class StreamChecker:

    def __init__(self, words: List[str]):
        self.letters = []
        self.trie = Trie()
        for word in words:
            self.trie.insert(word[::-1])
            # for example, stream is a, b, c, d, and word = 'cd', reverse both

    def query(self, letter: str) -> bool:
        self.letters.append(letter)
        i = len(self.letters) - 1
        node = self.trie.root
        while i >= 0: # reverse search
            if node.isWord:
                return True
            if self.letters[i] not in node.children:
                return False
            node = node.children[self.letters[i]]
            i -= 1
        return node.isWord
```

`StreamChecker(words)`: Constructor, init the data structure with the given words.

`query(letter)`: returns true if and only if for some `k >= 1`, **the last `k` characters queried** (in order from oldest to newest, including this letter just queried) spell one of the words in the given list.

```
StreamChecker streamChecker = new StreamChecker(["cd","f","kl"]);

// init the dictionary.

streamChecker.query('a');          // return false

streamChecker.query('b');          // return false

streamChecker.query('c');          // return false

streamChecker.query('d');          // return true, because 'cd' is in the wordlist
```

1233. Remove Sub-Folders from the Filesystem

```python
class Trie:
    def __init__(self):
        self.root = TrieNode()

    def insert(self, word):
        node = self.root
        for w in word:
            if w not in node.children:
                node.children[w] = TrieNode()
            node = node.children[w]
        node.word = True

    def find(self): # find prefix
        res = []
        def dfs(dirs, node):
            if node.word: # current node is leaf, append prev dirs
                res.append('/' + '/'.join(dirs))
                # print(dirs, res)
                return
            for nxt_node in node.children:
                dfs(dirs + [nxt_node], node.children[nxt_node])
        dfs([], self.root)
        return res

class Solution:
    def removeSubfolders(self, folder: List[str]) -> List[str]:
        trie = Trie()
        for f in folder:
            f = f.split('/')[1:] # split into list, remove empty
            trie.insert(f)
        return trie.find()
```

Input: folder = ["/a","/a/b","/c/d","/c/d/e","/c/f"]

Output: ["/a","/c/d","/c/f"]

421. Maximum XOR of Two Numbers in an Array

```python
class Solution0:
    def findMaximumXOR(self, nums: List[int]) -> int:
        trie, res = Trie(), 0
        for num in nums:
            trie.insert(num)

        for num in nums:
            node = trie.root
            res = max(res, trie.query(num))
        return res

class Trie:
    def __init__(self):
        self.root = {}

    def insert(self, num):
        p = self.root
        for i in range(31, -1, -1):
            cur = (num >> i) & 1
            if cur not in p:
                p[cur] = {}
            p = p[cur]

    def query(self, num):
        if not self.root:
            return -1
        p, res = self.root, 0
        for i in range(31, -1, -1):
            cur = (num >> i) & 1
            if 1 - cur in p:
                p = p[1 - cur]
                res |= (1 << i)
            else:
                p = p[cur]
        return res
```

Given an integer array `nums`, return *the maximum result of* `nums[i] XOR nums[j]`, where $0 \leqslant i \leqslant j < n$.

Follow up: Could you do this in `O(n)` runtime?

```python
class Solution1:
    def findMaximumXOR(self, nums):
        """
        :type nums: List[int]
        :rtype: int
        https://www.youtube.com/watch?v=ZHtZfkAcPKc&t=54s
        """
        # Build the answer bit by bit from left to right
        # a ^ b = res => a ^ res = b
        res = 0
        for i in range(31, -1, -1):
            res <<= 1
            prefixes = {num >> i for num in nums} # get prefix(bits) for each num
            nxt = res + 1 # get next biggest mask based on last round res
            if any(nxt ^ p in prefixes for p in prefixes):
                res = nxt
            # res += any(nxt ^ p in prefixes for p in prefixes)
            # print(bin(res)[2:], [bin(pre)[2:] for pre in prefixes])
        return res
```

1707. Maximum XOR With an Element From Array

```python
class Solution:
    def maximizeXor(self, nums: List[int], queries: List[List[int]]) -> List[int]:
        nums.sort()
        trie, n = Trie(), len(queries)
        queries_sort = sorted(enumerate(queries), key=lambda x: x[1][1]) # sorted by m

        res, j = [-1] * n, 0
        for i, (x, m) in queries_sort:
            while j < len(nums) and nums[j] < m:
                trie.insert(nums[j])
                j += 1
            res[i] = trie.query(x)
        return res


class Trie:
    def __init__(self):
        self.root = {}

    def insert(self, num):
        node = self.root
        for i in range(31, -1, -1):
            bit = (num >> i) & 1 # get i-th bit
            if bit not in node:
                node[bit] = {}
            node = node[bit]

    def query(self, num):
        # O(32)
        if not self.root: # no node
            return -1
        node, res = self.root, 0
        for i in range(31, -1, -1):
            bit = (num >> i) & 1 # get i-th bit
            if 1 - bit in node: # greedy, chose complement
                # find a 1/0, go to node.zero/node.one
                node = node[1 - bit]
                res |= (1 << i)
            else: # only one path, follow it
                node = node[bit]
        return res
```

You are given an array `nums` consisting of non-negative integers. You are also given a `queries` array, where `queries[i] = [xi, mi]`.

The answer to the `ith` query is the maximum bitwise `XOR` value of `xi` and any element of `nums` that does not exceed `mi`. In other words, the answer is `max(nums[j] XOR xi)` for all `j` such that `nums[j] <= mi`. If all elements in `nums` are larger than `mi`, then the answer is `-1`.

Return *an integer array* `answer` *where* `answer.length == queries.length` *and* `answer[i]` *is the answer to the* `ith` *query.*

`Input: nums = [0,1,2,3,4], queries = [[3,1],[1,3],[5,6]]`

`Output: [3,3,7]`

`Explanation:`

`1) 0 and 1 are the only two integers not greater than 1. 0 XOR 3 = 3 and 1 XOR 3 = 2. The larger of the two is 3.`

`2) 1 XOR 2 = 3.`