SC1007 Data Structures and Algorithms

Week 11: Trie

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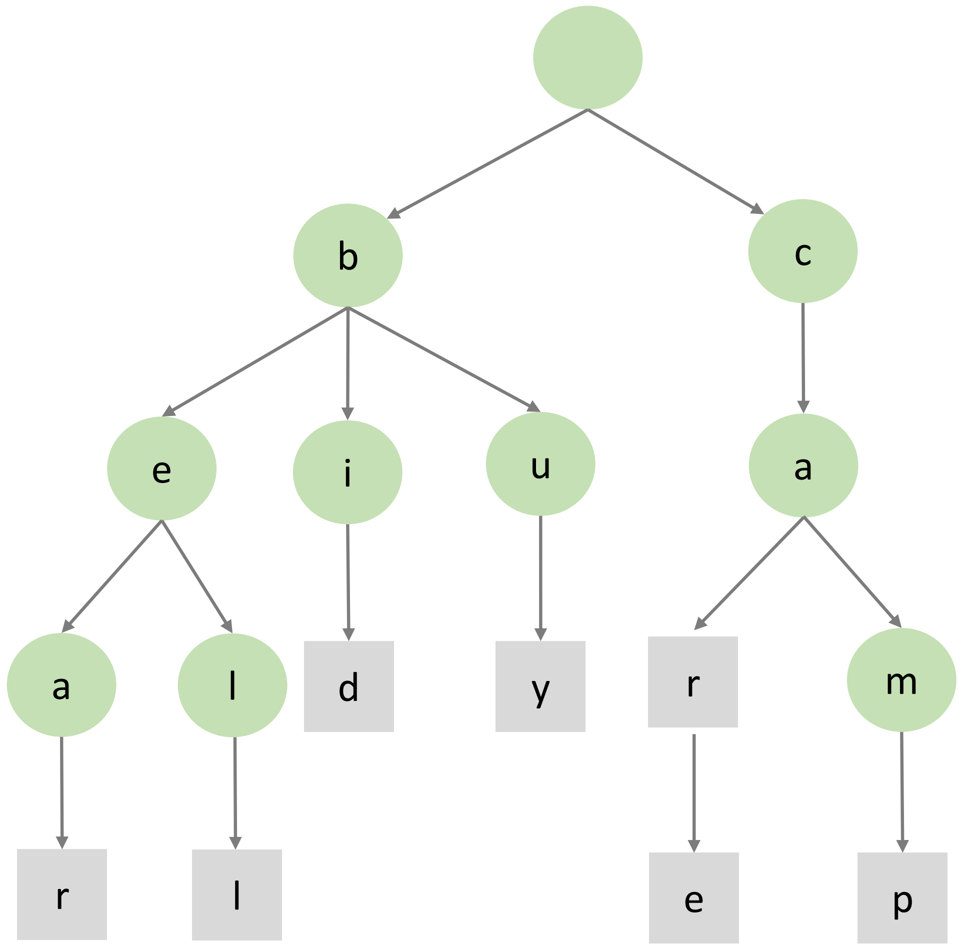
Overview

- What is a trie
- Implementations with linked list
  - Insert a word
  - Search a word
  - Traversal of a trie
- Application examples
  - Print all words
  - Autocomplete
  - Spell checking

What Is a Trie

- A tree-based data structure used for efficient string operations. Also called prefix tree or digital tree.
- It is a specialized search tree data structure used to store and retrieve strings from a dictionary or set.



The trie structure for strings: bear, bell, bid, buy, car, care, camp

Applications of Trie

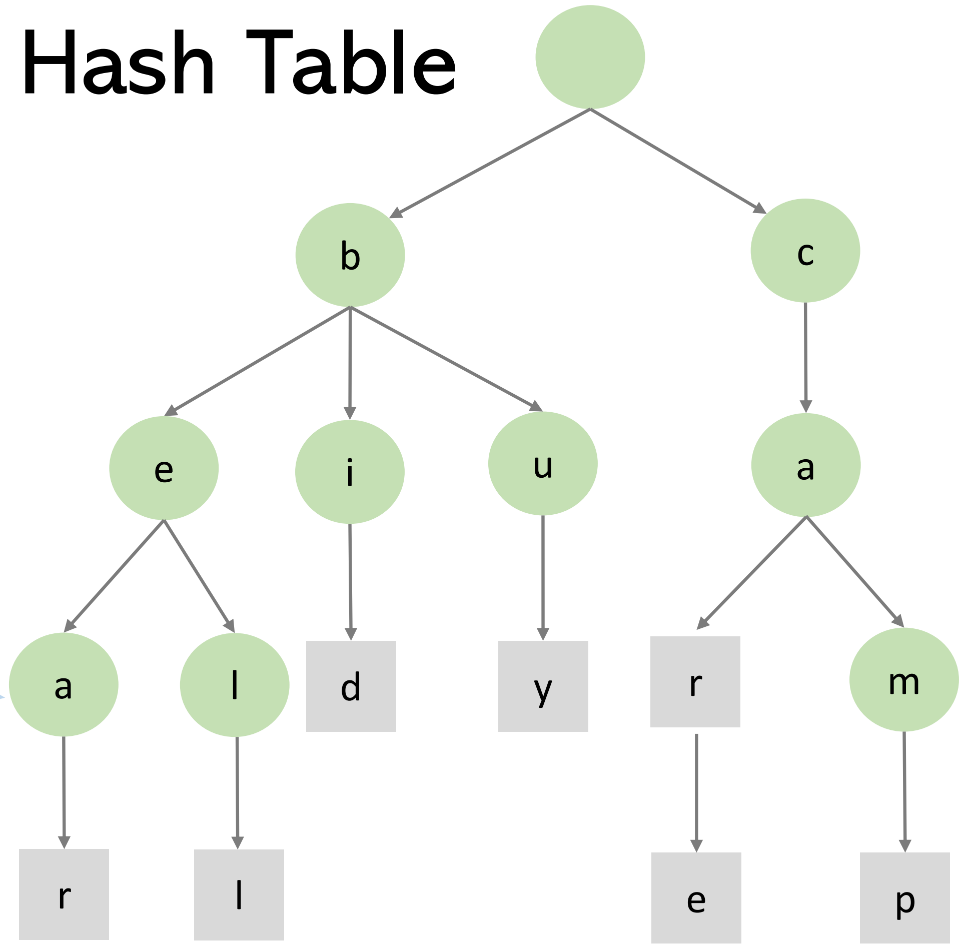
- Autocomplete
  - Google Search and mobile keyboards use tries to suggest completions as you type. This allows fast lookups of possible word completions.
- Spell Checking
  - Tries enable efficient verification of word existence in dictionaries. They also help generate word suggestions for misspelled words.
- Technical Applications
  - IP routing tables use tries for address lookup. Compression algorithms leverage tries for pattern recognition.

Implementations with Hash Table

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

- Each node in the Trie will be a dictionary with:
  - keys → characters
  - values → child nodes (also dictionaries)
  - "is_end_of_word" mark

```
children = {'r':TrieNode(children={},
                         is_end_of_word=True)}
is_end_of_word = False
```

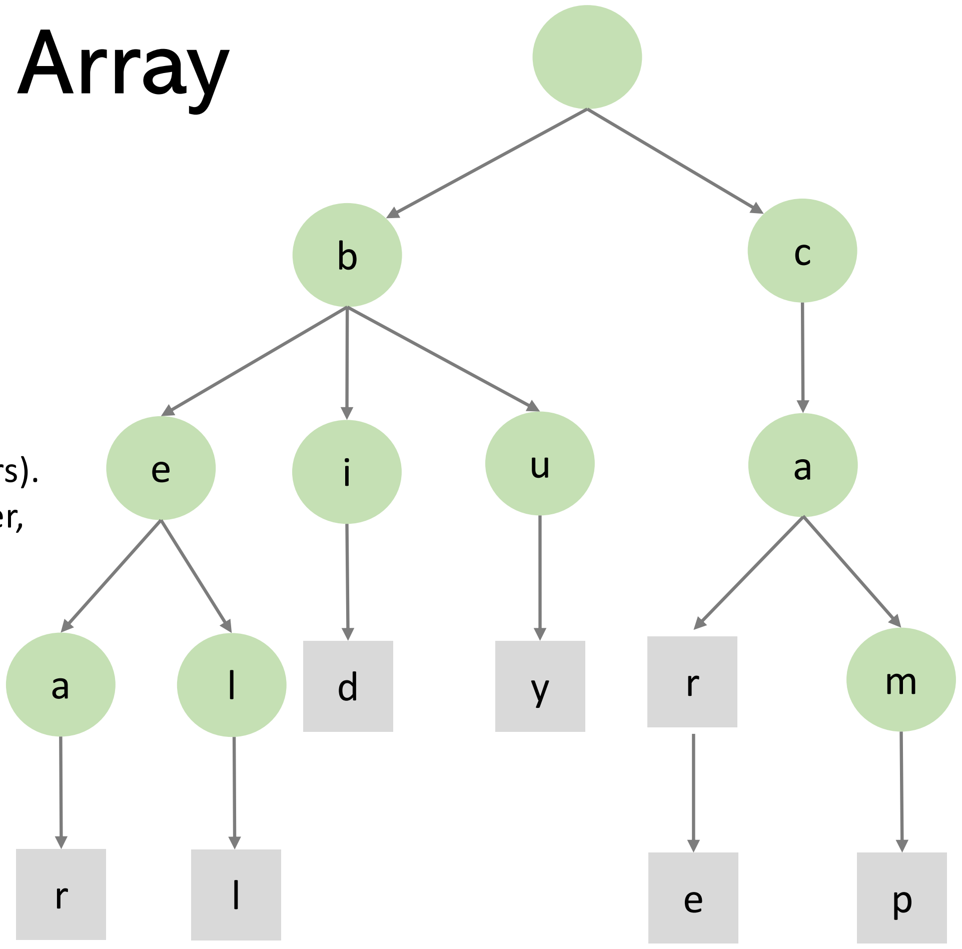


Implementations with Array

```
class TrieNode:
    def __init__(self):
        self.children = [None] * 26
        self.is_end_of_word = False
```

- Each node maintains a **fixed-size array** of children, one for each possible character (e.g., 26 for lowercase English letters).
- Each position in the array corresponds to a specific character, e.g. index 0 for 'a', 1 for 'b', ..., 25 for 'z'.

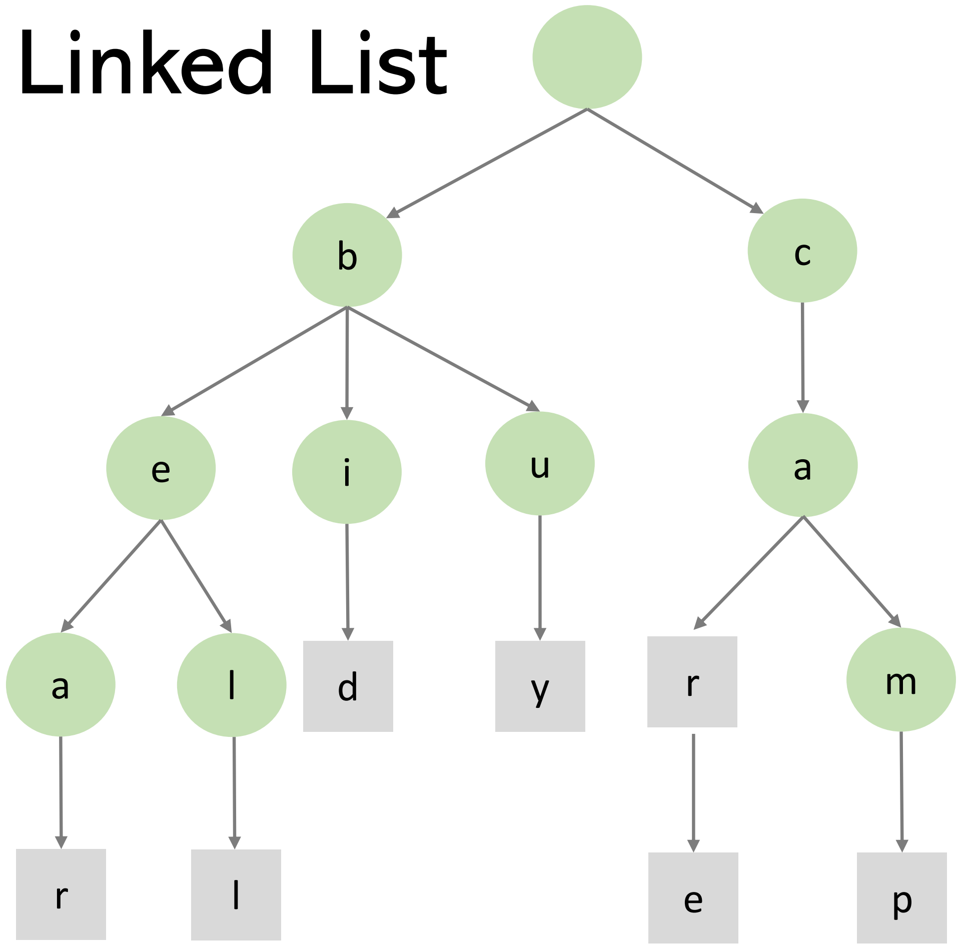
```
child[17] = TrieNode(
        children = [None]*26,
        is_end_of_word = True)
end_of_word = False
```



Implementations with Linked List

```
class TrieNode:
    def __init__(self, char):
        self.char = char
        self.is_end_of_word = False
        self.child = None
        self.next = None
```

```
char = 'a'
end_of_word = False
child = TrieNode('r')
next = TrieNode('l')
```



Implementations with Linked List

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class TrieNode:
    def __init__(self, char):
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```
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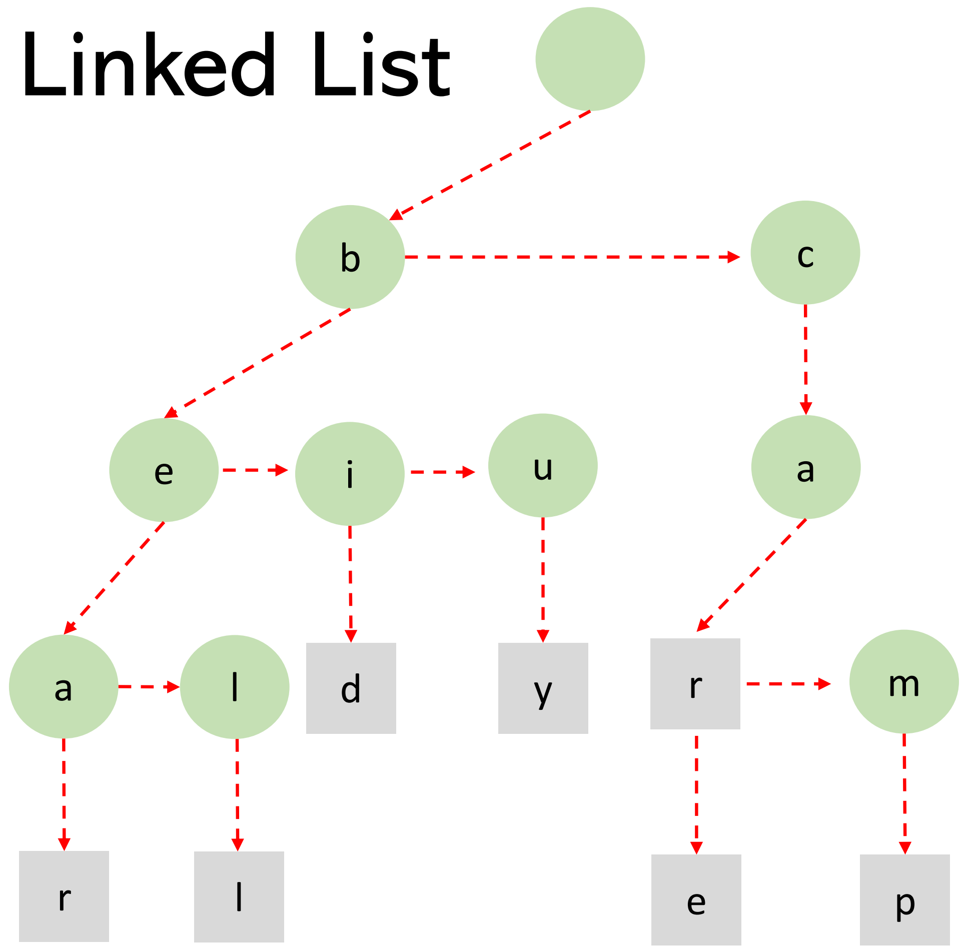


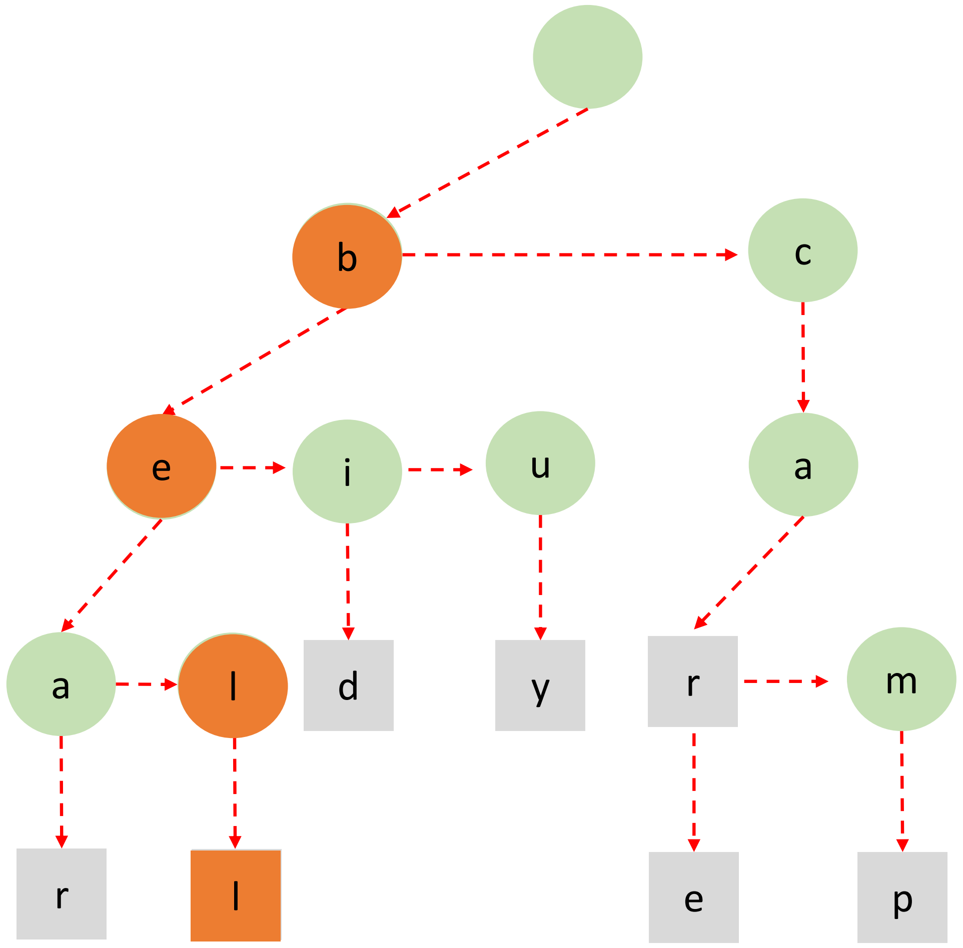
Implementations with Linked List

- The core operations for a trie:
  - Search a word
  - Insert a word
  - Traversal
- Usually we will not delete a word from a trie
  - Dictionaries don’t usually change
  - Deleting from a trie is much more complex than inserting
- The binary tree traversal algorithms can be applied in trie
  - Preorder (dfs)
  - Level-by-level (bfs)

```
class Trie:
    def __init__(self):
        self.root = TrieNode("")
    def search(self, word):
    def insert(self, word):
    def dfs(self,node):
    def bfs(self,node):
```

Search a Word

```
parent_node = root
for each character in the word
       if the current character is a
       child of parent_node:
              parent_node = current_node
              move on to the next character
       else:
              return False
return current_node.is_end_of_word
```

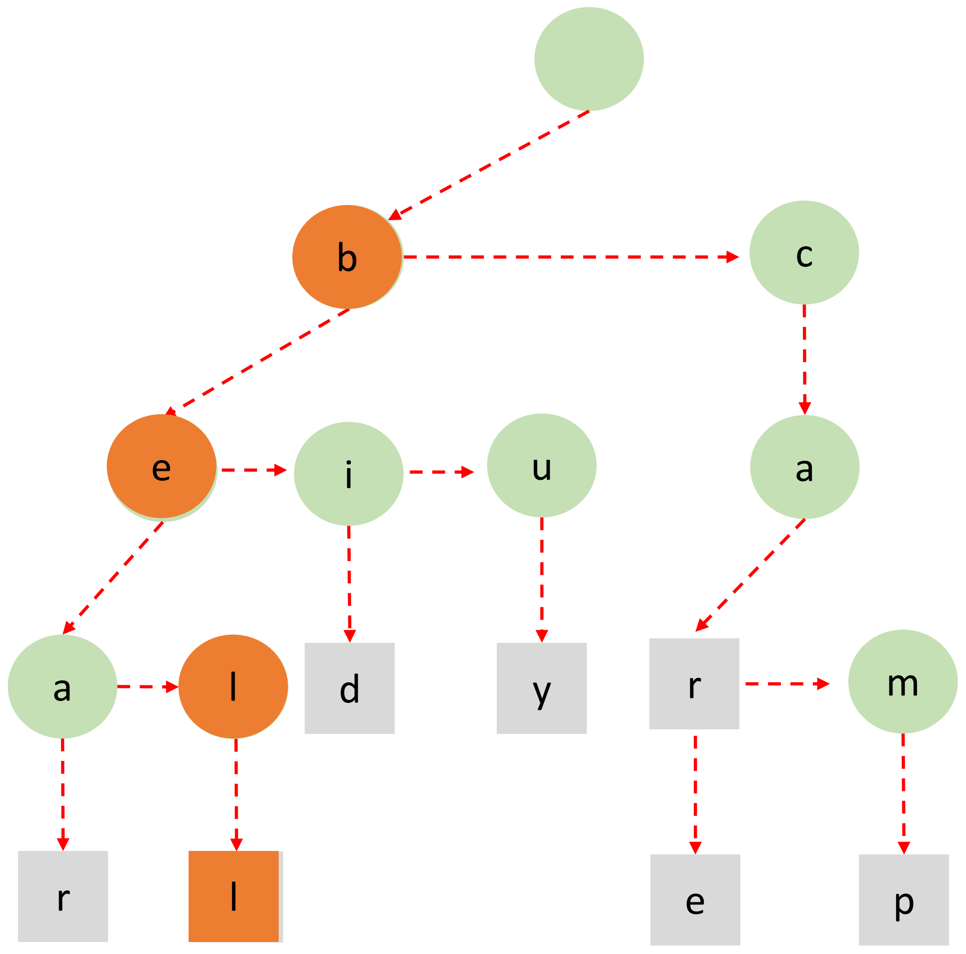


For example, search "bell"

Search a Word

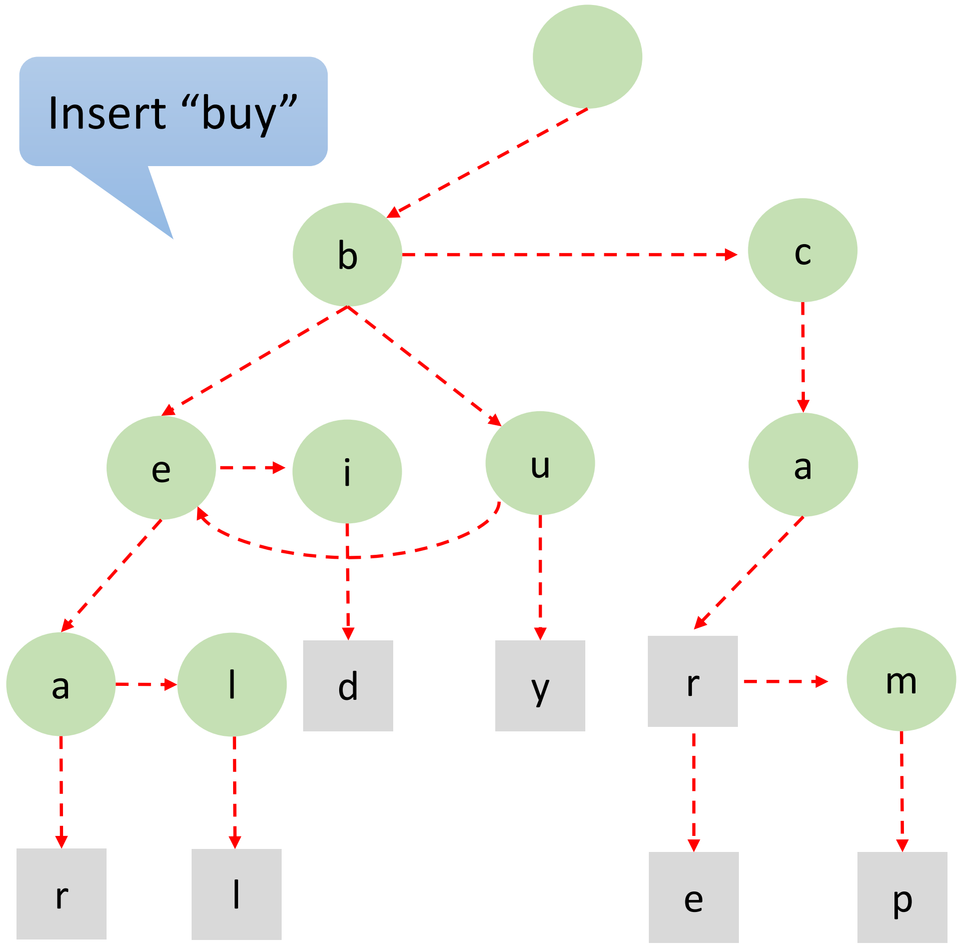
```
def _find_child(self, node, char):
    current = node.child
    while current:
        if current.char == char:
            return current
        current = current.next
    return None

def search(self, word):
    node = self.root
    for char in word:
        node = self._find_child(node, char)
        if not node:
            return False
    return node.is_end_of_word
```



For example, search "bell"

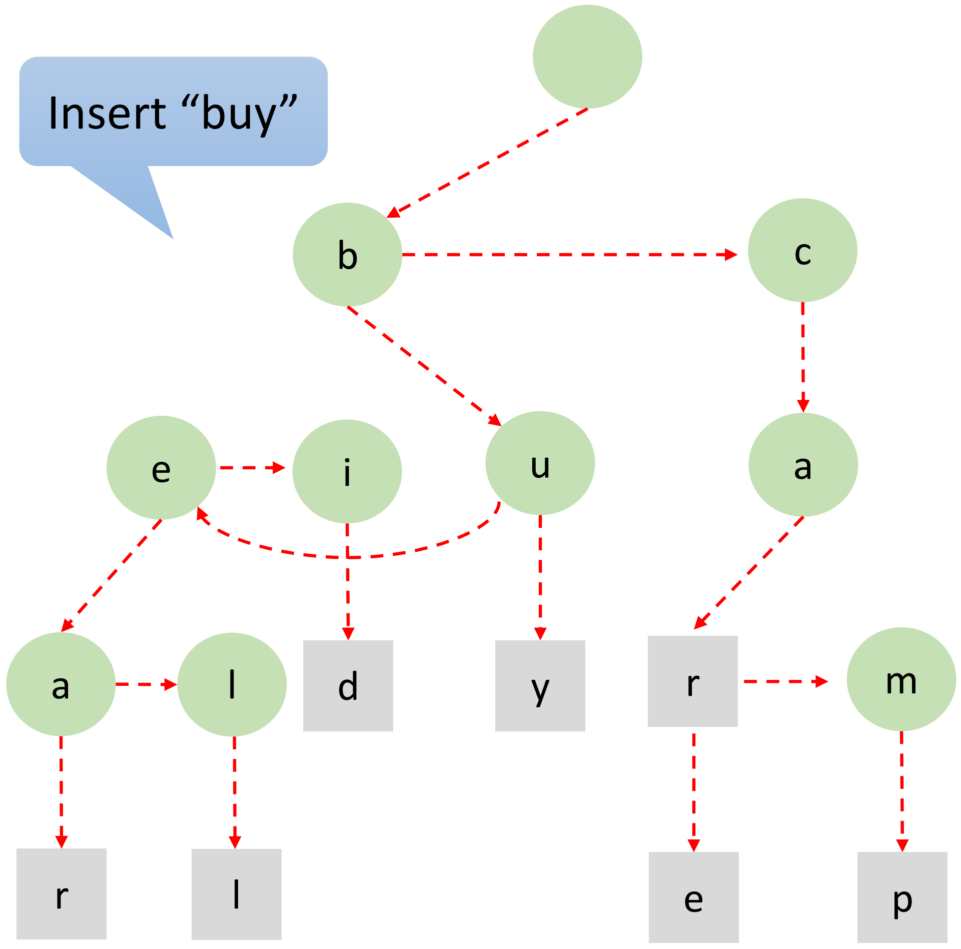
Insert a Word



```
for each character in the word:
    if the character is a child node of
    the parent node:
        move to the next character
    else:
        new_node = create a new TrieNode
        #insert the child at the beginning
        #of the linked list
        set the new_node next be the
        parent_node’s first child
        set the parent_node first child be
        the new_node

set end_of_word of the last_node as True
```

Insert a word



```
def _add_child(self, node, char):
     new_node = TrieNode(char)
     new_node.next = node.child
     node.child = new_node
     return new_node

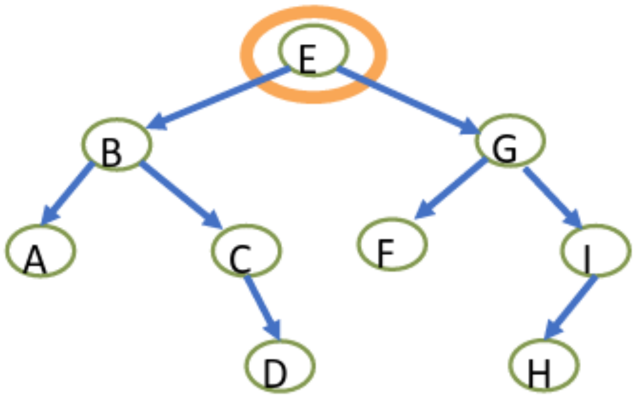
def insert(self, word):
    node = self.root
    for char in word:
        child = self._find_child(node, char)
        if not child:
            child = self._add_child(node, char)
        node = child
     node.is_end_of_word = True
```

Lab Practice

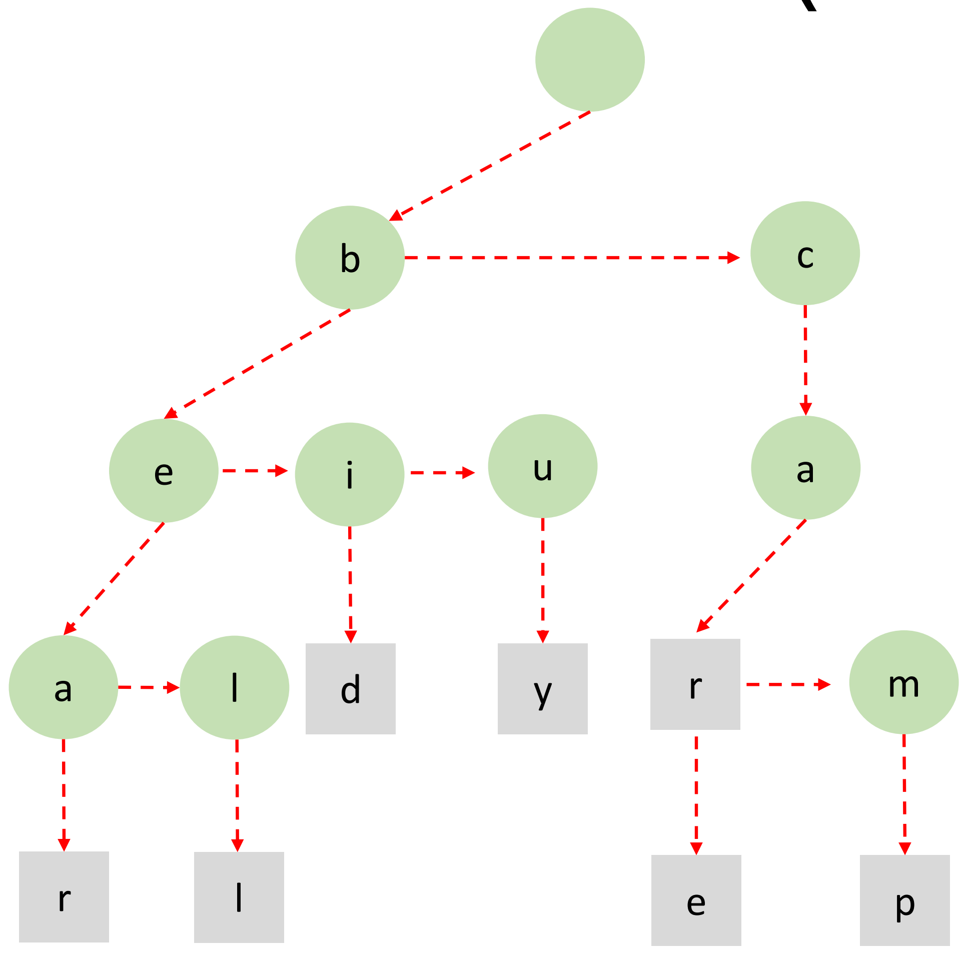
Pre-order Depth First Traversal

- Pre-order
  - **Process the current node's data**
  - **Visit the left child subtree**
  - **Visit the right child subtree**

```
TreeTraversal(Node N):
    Visit N;
    If (N has left child)
        TreeTraversal(LeftChild);
    If (N has right child)
        TreeTraversal(RightChild);
    Return; // return to parent
```



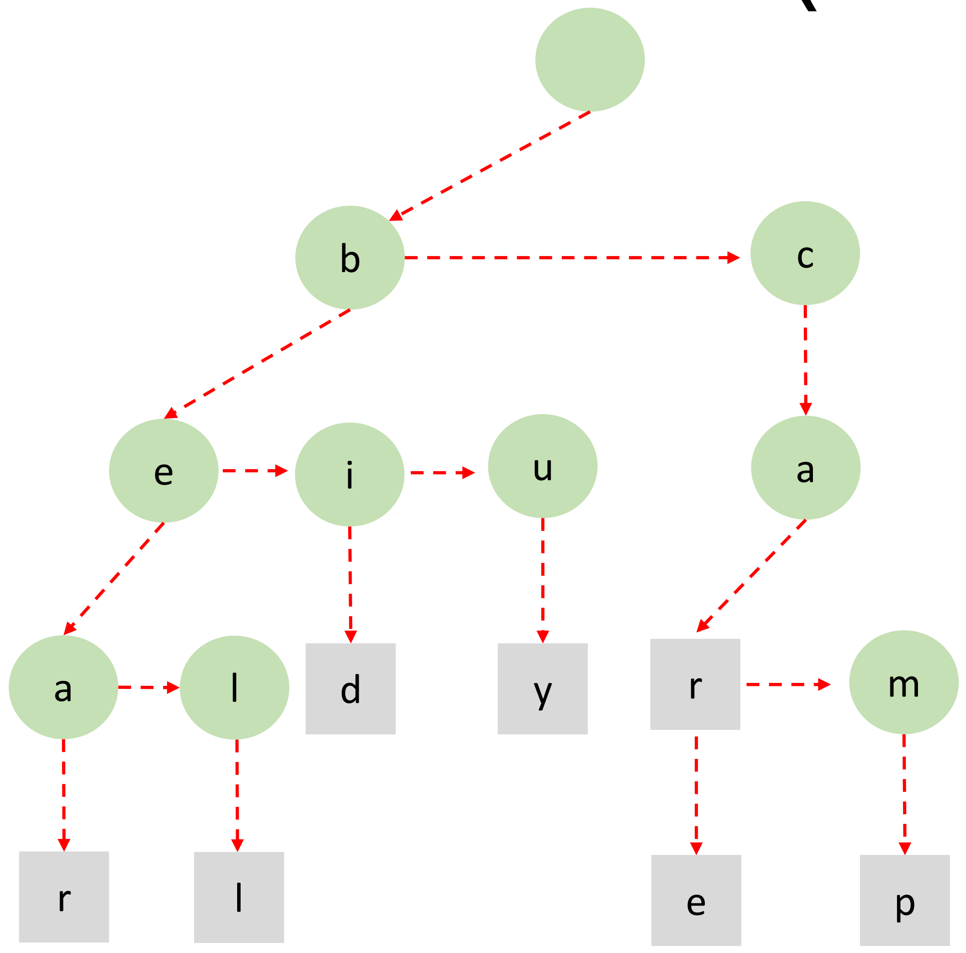
Preorder Traversal (DFS)



Instead of visiting left and right children, visit each child of the TrieNode

```
dfs(TrieNode tn):
    visit tn
    child = tn.child
    while child is not None:
        dfs(child)
        child = child.next
```

Preorder Traversal (DFS)



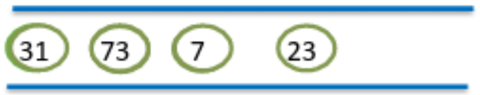
```
def dfs(self, node):
    if node is not None:
        print(node.char, end=" ")
    child = node.child
    while child:
        self.dfs(child)
        child = child.next
```

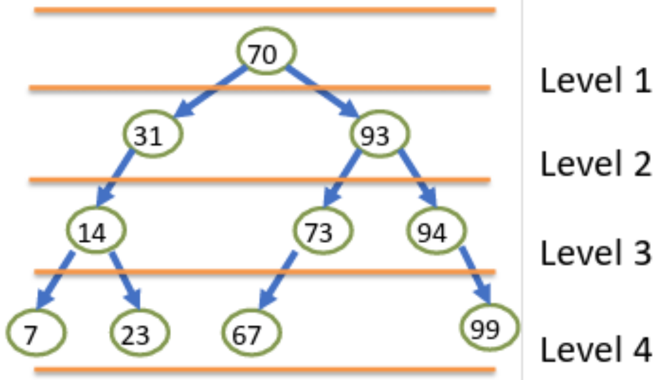
None b e a r l l l d u y c a r e m p

Breath-first Traversal: Level-by-level

Level-By-Level Traversal:

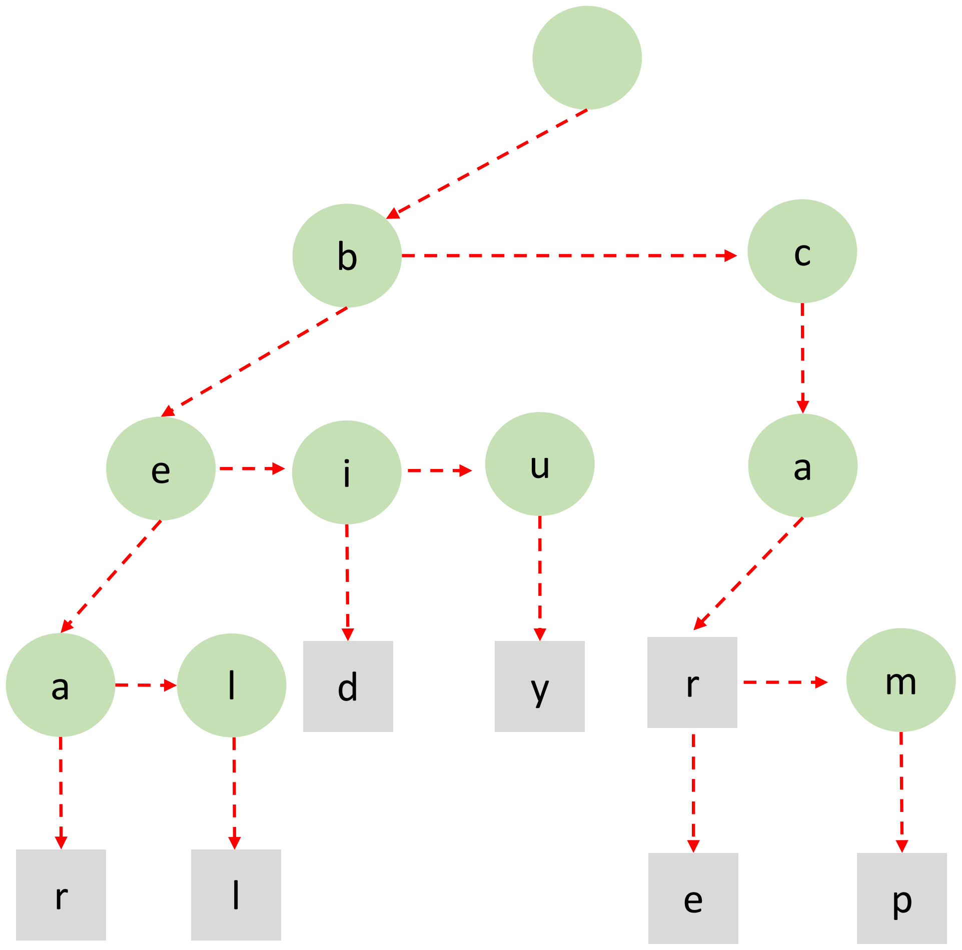
- Visiting a node
- Remember all its children
    - Use a queue (FIFO structure)





1. Enqueue the current node
2. Dequeue a node
3. Enqueue its children if it is available
4. Repeat Step 2 until the queue is empty

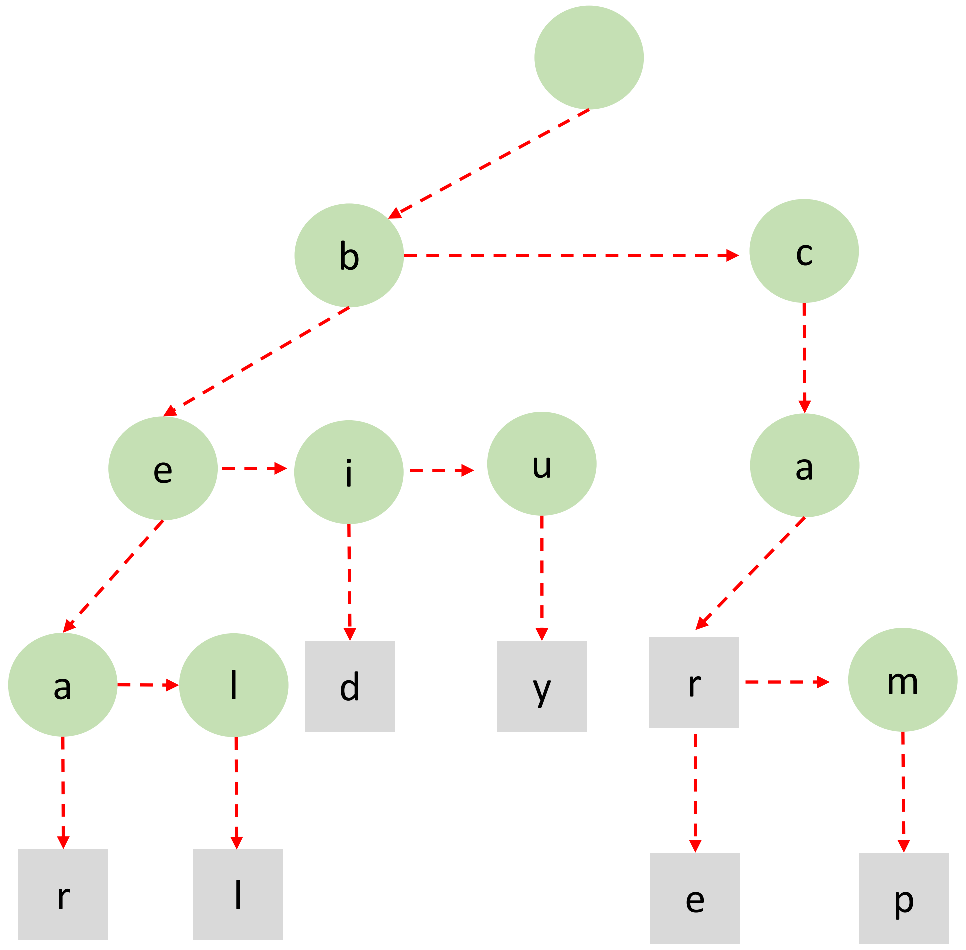
Level-by-Level Traversal (BFS)



```
def bfs(self):
    queue = Queue()
    queue.enqueue(self.root)
    while not queue.is_empty():
        node = queue.dequeue()
        print(node.char, end=" ")
        child = node.child
        while child:
            queue.enqueue(child)
            child = child.next
```

```
None b c e i u a a l d y r m r l e p
```

Working Example: Print All Words

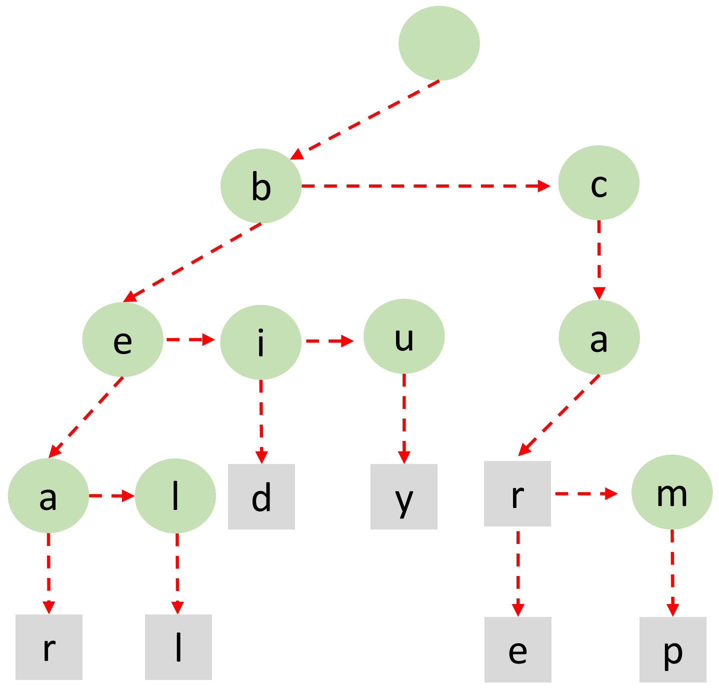


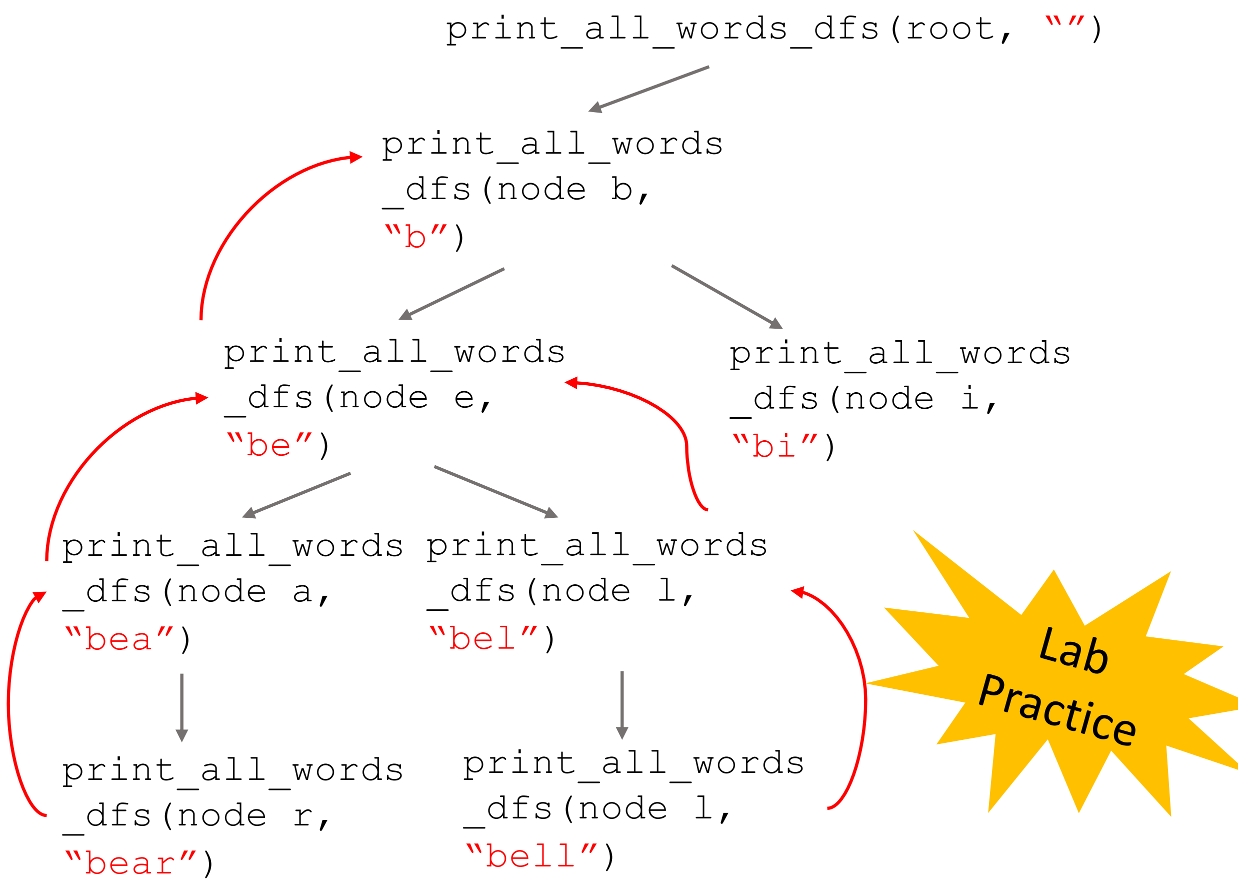
- Apply dfs
- When the node is the end of a word, print it
- Keep track of current nodes' ancestors

```
def print_all_words_dfs(self, node, prefix):
    if node.is_end_of_word:
        print(prefix)

    child = node.child
    while child:
        self. print_all_words(child,
                              prefix+child.char)
        child = child.next
```

Working Example: Print All Words





```
print_all_words_dfs(root, “”)

print_all_words
_dfs(node b,
“b”)

print_all_words
_dfs(node e,
“be”)

print_all_words
_dfs(node i,
“bi”)

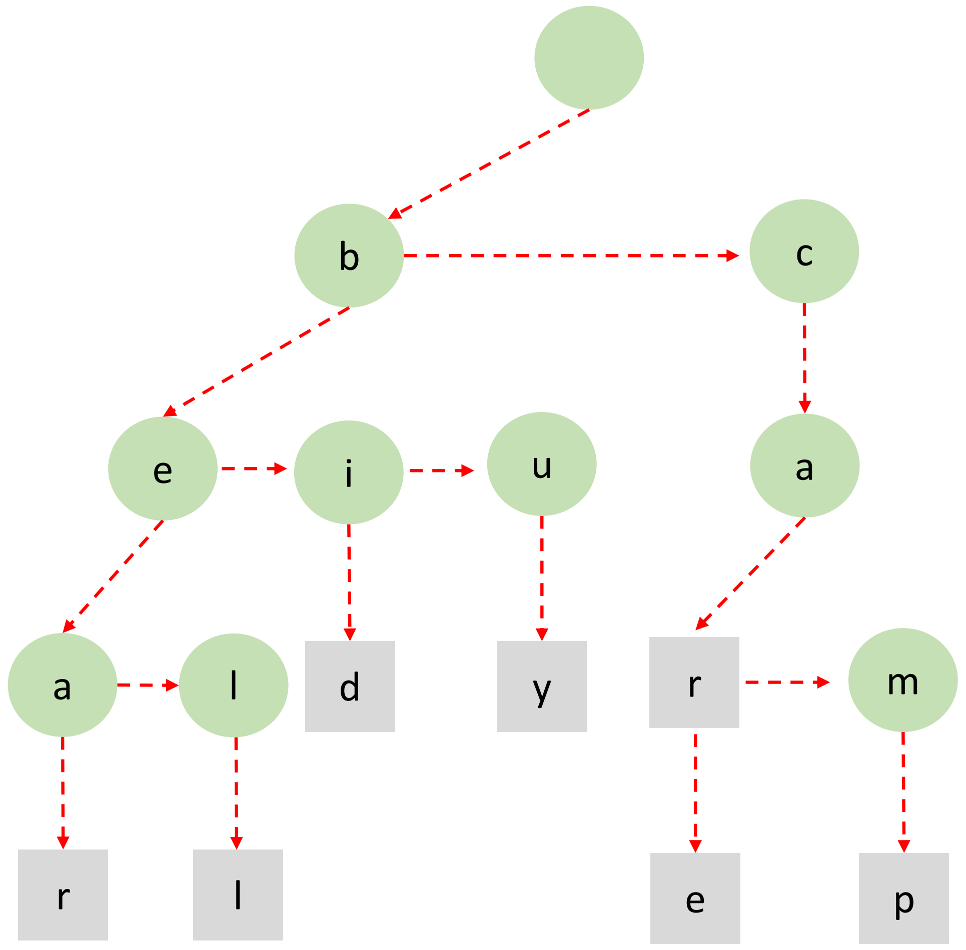
print_all_words
_dfs(node a,
“bea”)

print_all_words
_dfs(node l,
“bel”)

print_all_words
_dfs(node r,
“bear”)

print_all_words
_dfs(node l,
“bell”)
```

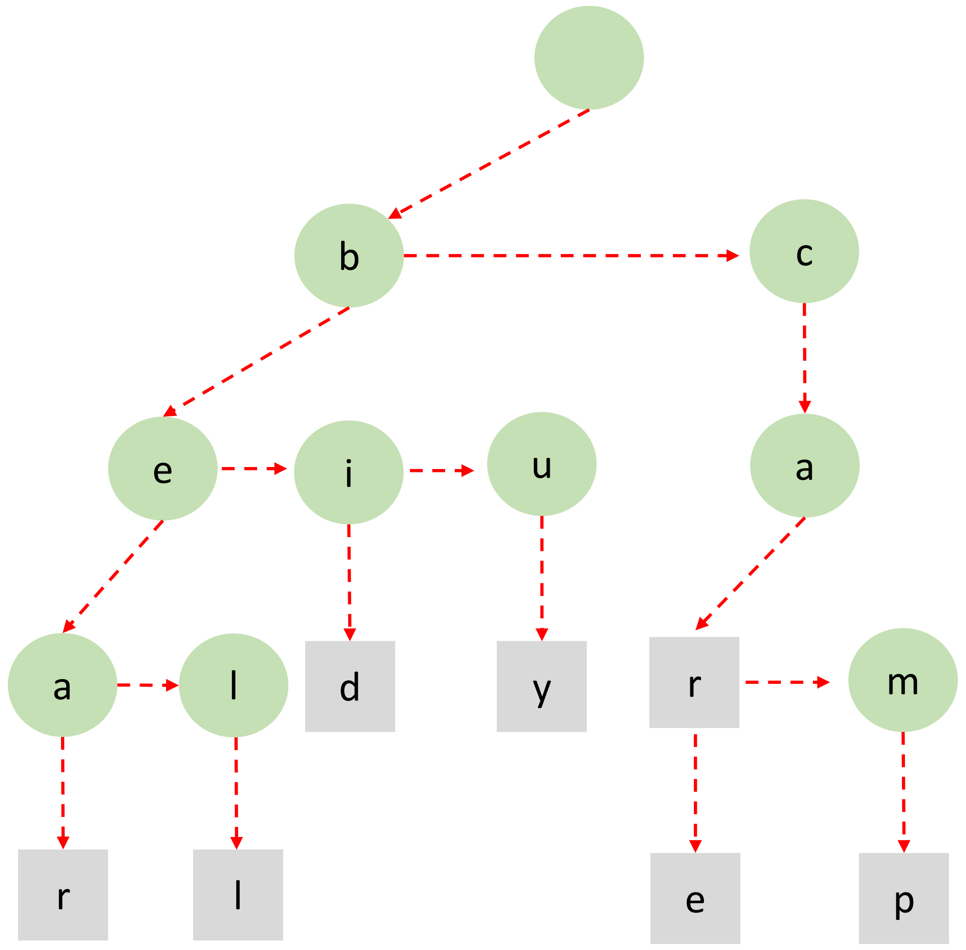
Working Example: Print All Words



- Apply bfs
- When enqueue a node, also enqueue the node's ancestors & the node's character
- When dequeue a node, if the node is end of a word, print the word

```
class Queue:
    def __init__(self):
        self.items = []
    def enqueue(self, item):
        self.items.append(item)
    def dequeue(self):
        if not self.is_empty():
            return self.items.pop(0)
        return None
    def is_empty(self):
        return len(self.items) == 0
```

Working Example: Print All Words

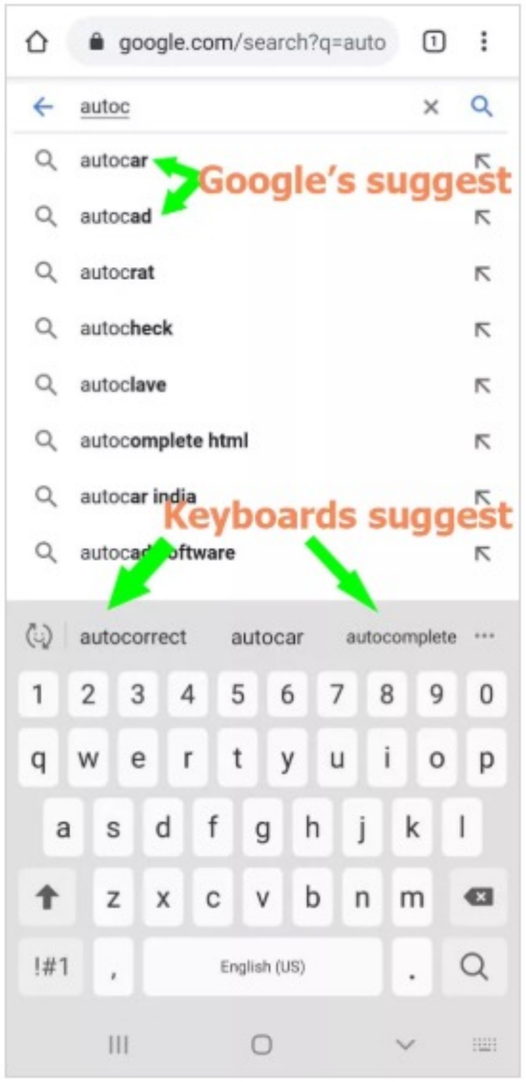


```
def print_all_words_bfs(self):
    queue = Queue()
    queue.enqueue((self.root, ""))
    while not queue.is_empty():
        node, prefix = queue.dequeue()
        if node.is_end_of_word:
            print(prefix)
        child = node.child
        while child:
            queue.enqueue((child,
                           prefix + child.char))
            child = child.next
```

Tutorial Practice

Application Example: Autocomplete

- Suggests possible words based on a given prefix
- Common in search bars, text editors, messaging apps
- Needs fast prefix lookup for responsiveness as you type.
- Use a trie
  - Efficient prefix-based search
  - Stores multiple words compactly using shared prefixes



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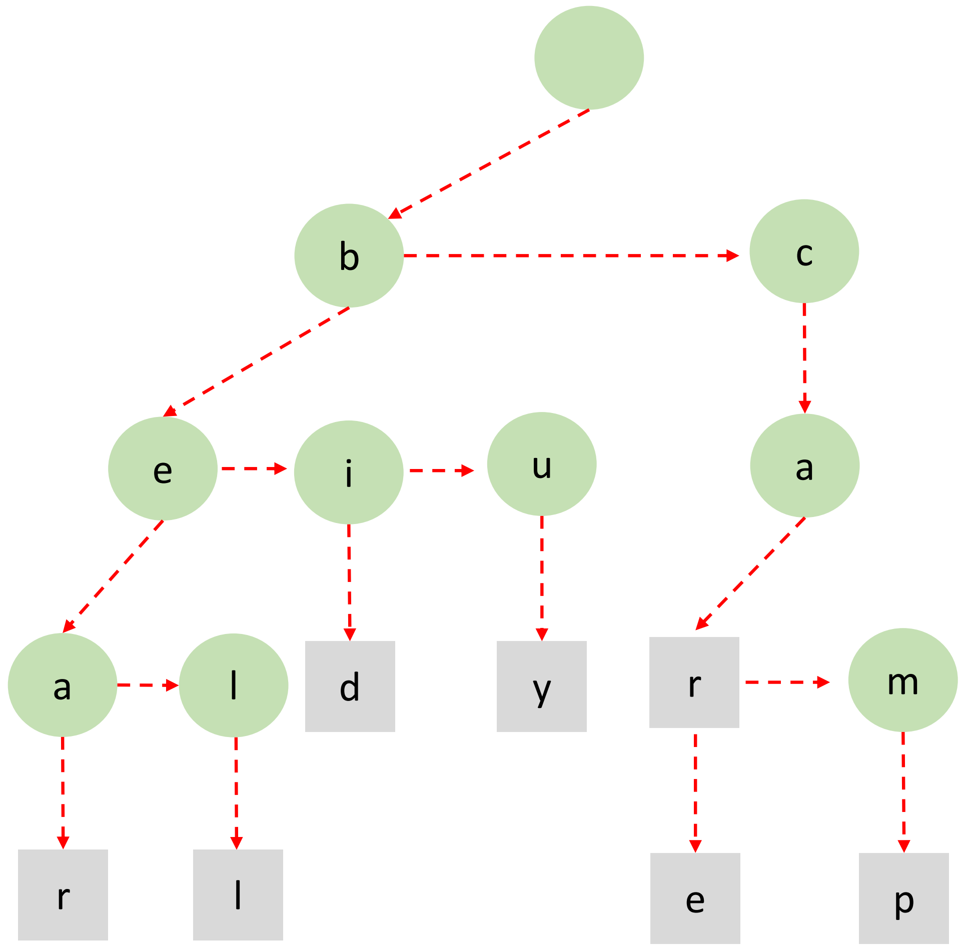
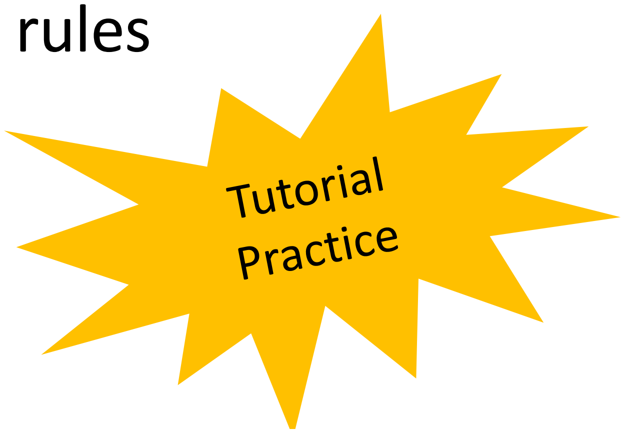
autocomplete html
autocar india
autocad software

autocorrect autocar autocomplete

Application Example: Autocomplete

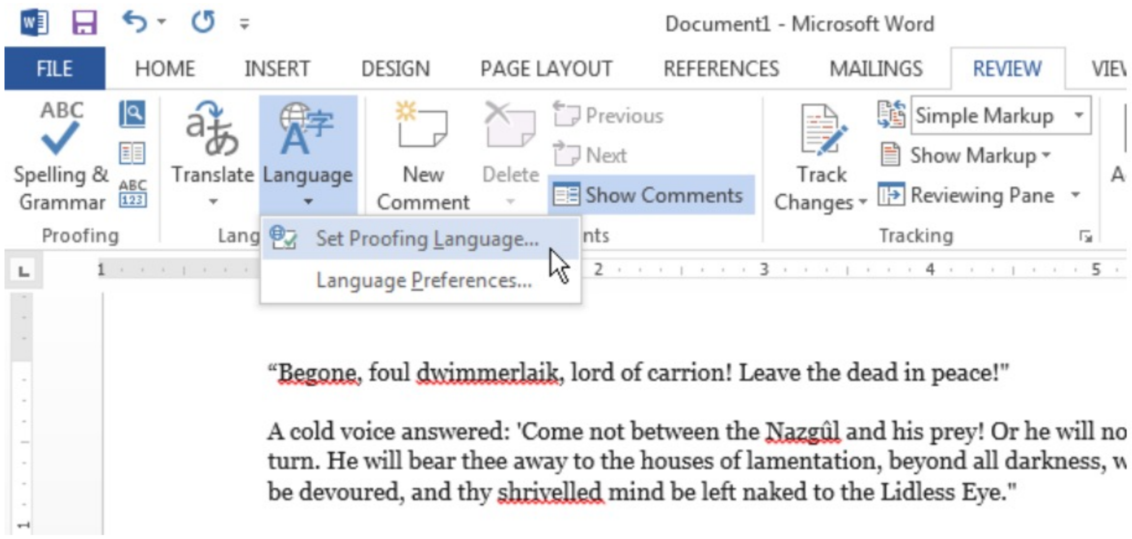


- Traverse the Trie to the node matching the prefix, e.g., “ca”
- Perform dfs/bfs to collect all complete words
- Rank the words based on some rules



Application Example: Spell Checking

- Check if a word is valid
- Suggest corrections for misspelled words
- It is common in:
  - Word processors
  - Messaging apps
  - Search engines

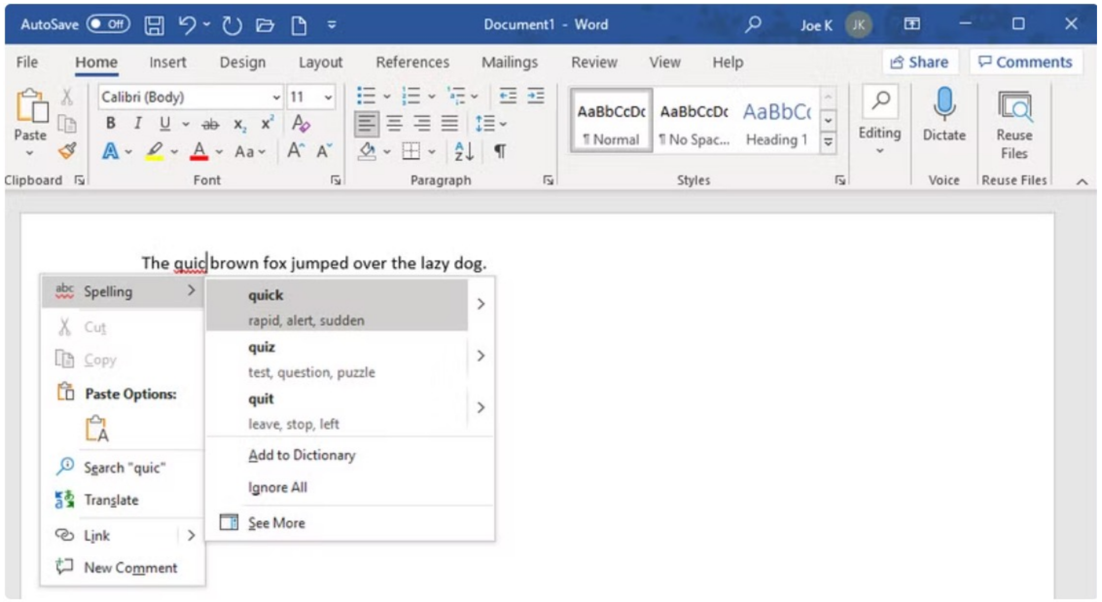


"Begone, foul dwimmerlaik, lord of carrion! Leave the dead in peace!"

A cold voice answered: 'Come not between the Nazgûl and his prey! Or he will no
turn. He will bear thee away to the houses of lamentation, beyond all darkness, w
be devoured, and thy shrivelled mind be left naked to the Lidless Eye."

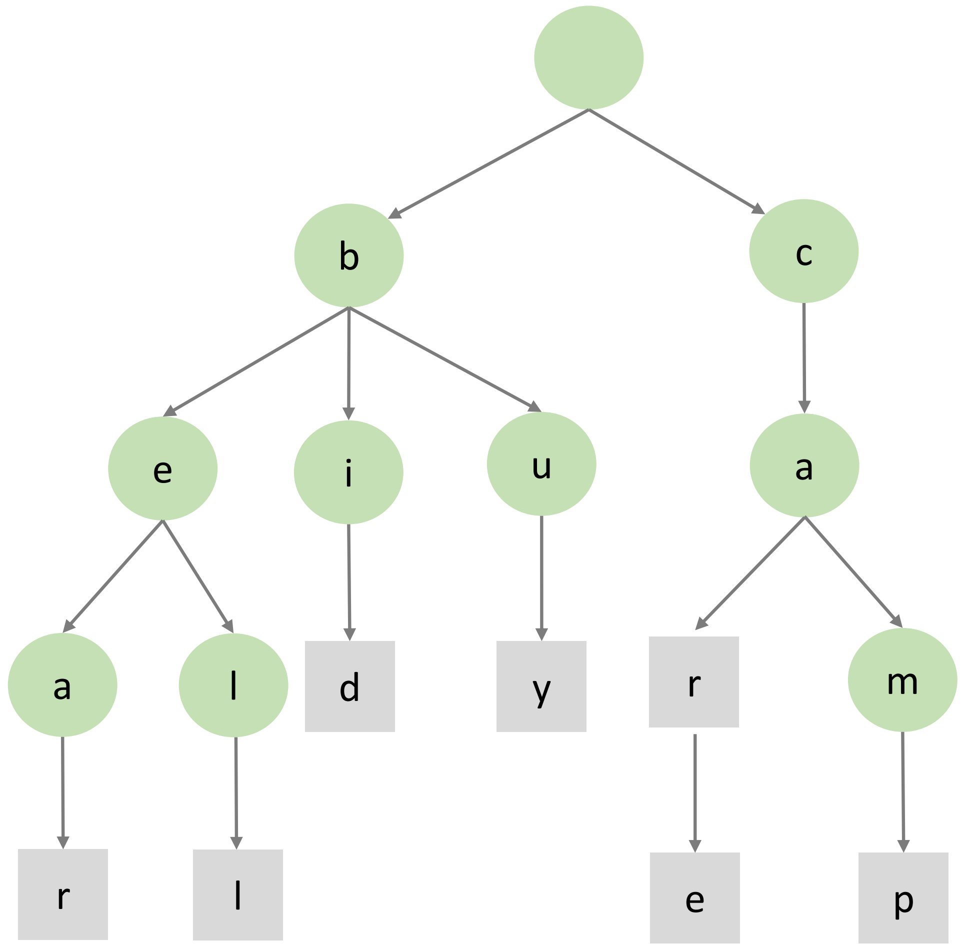
Application Example: Spell Checking

- Check if a word is valid
  - Search a word in the trie
- Suggest corrections for misspelled words
  - Prefix
  - Edit distance, e.g., Levenshtein distance
  - Frequency ranking
  - User history/context
  - ….


The quic brown fox jumped over the lazy dog.

Summary

- A tree-based data structure used for efficient string operations.
- Implementations with linked list
  - Insert a word
  - Search a word
  - Traversal of a trie: dfs and bfs
- Examples
  - Print all words
  - Autocomplete
  - Spell checking



The trie structure for strings: bear, bell, bid, buy, car, care, camp