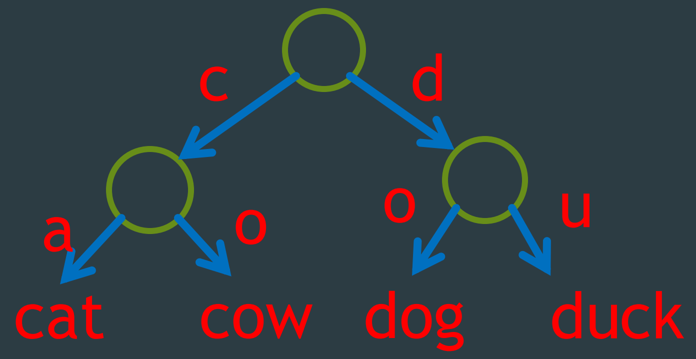
ECE2810J
Data Structures and Algorithms

Tries

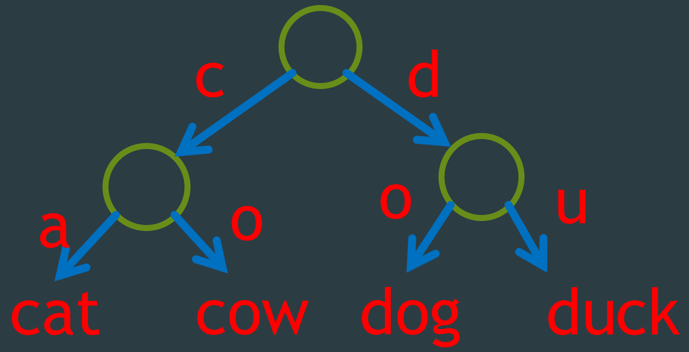
- **Learning Objectives:**
- Know what a trie is and understand its difference between binary search trees
- Know how to implement search, insertion, and removal for a trie

Trie

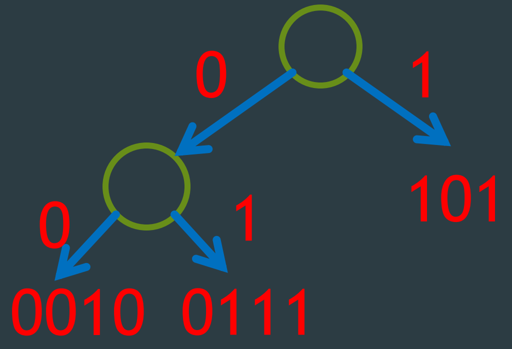
- The word “trie” comes from retrieval.
  - To distinguish with “tree”, it is pronounced as “try”.
- A trie is a tree that uses parts of the key, as opposed to the whole key, to perform search.
- Data records are only stored in leaf nodes. Internal nodes do not store records; they are “**branch**” points to direct the search process.



Trie

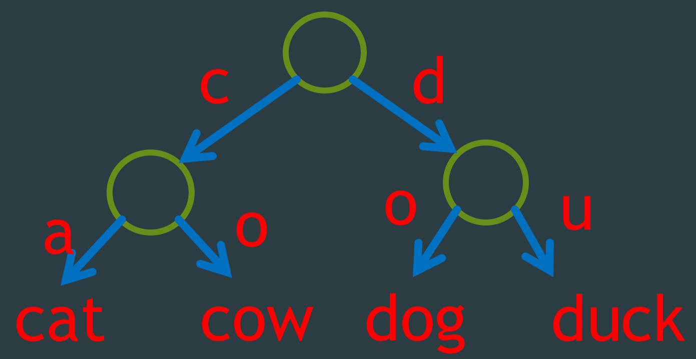


- Trie usually is used to store a set of strings from an alphabet.
  - The alphabet is in the general sense, not necessarily the English alphabet.
- For example, {0, 1} is an alphabet for binary codes {0010, 0111, 101}. We can store these three codes using a trie.



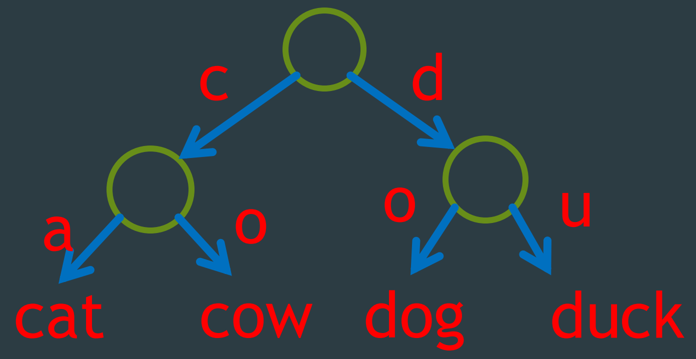
Trie

- Each edge of the trie is labeled with symbols from the alphabet.
- Labels of edges on the path from the root to any leaf in the trie forms a **prefix** of a string in that leaf.
  - Trie is also called prefix-tree.



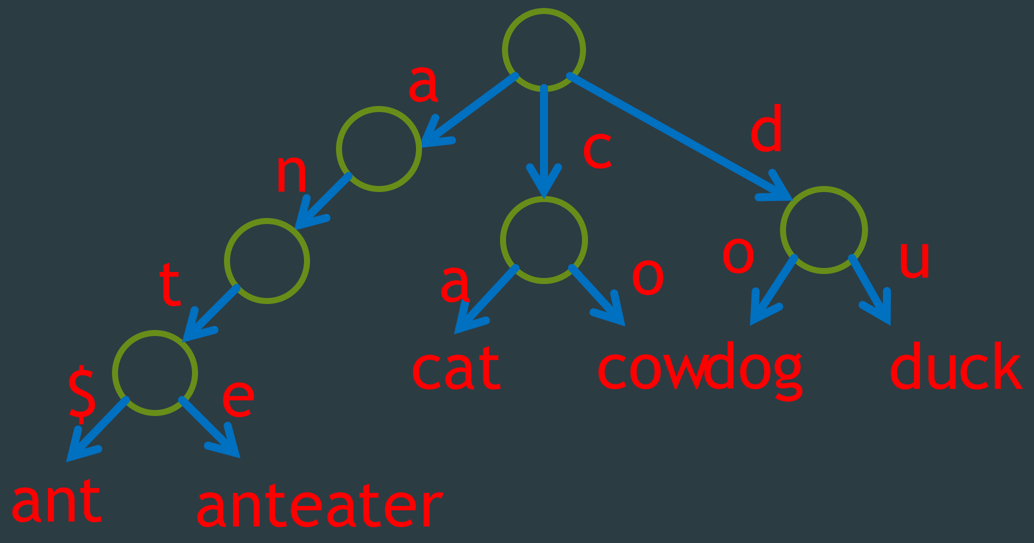
Trie

- The most significant symbol in a string determines the branch direction at the root.
- Each internal node is a "**branch**" point.
- As long as there is only one key in a branch, we do not need any further internal node below that branch; we can put the word directly as the leaf of that branch.



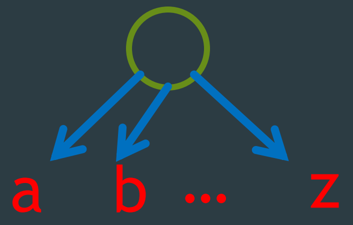
Trie Implementation Issue

- Sometimes, a string in the set is exactly a prefix of another string.
  - For example, “ant” is a prefix of “anteater”.
  - How can we make “ant” as a leaf in the trie?
- We add a symbol to the alphabet to indicate the end of a string. For example, use “$” to indicate the end.

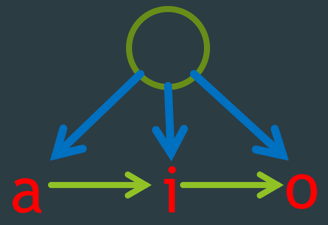


Trie Implementation Issue

- We can keep an array of pointers in a node, which corresponds to **all** possible symbols in the alphabet.

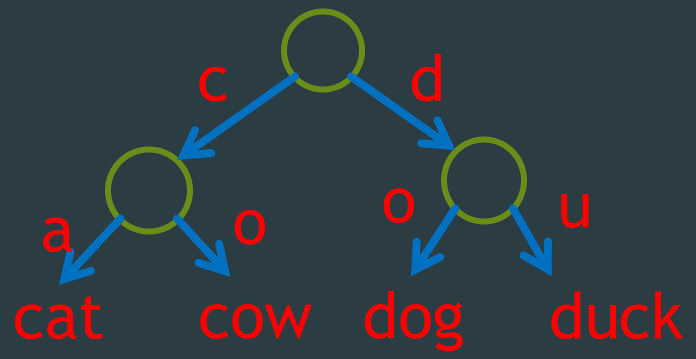


- However, most internal nodes have branches to only a small fraction of the possible symbols in the alphabet.
  - An alternate implementation is to store a linked list of pointers to the child nodes.



Trie Search

- Follow the search path, starting from the root.
- When there is no branch, return false.
- When the search leads to a leaf, further compare with the key at the leaf.

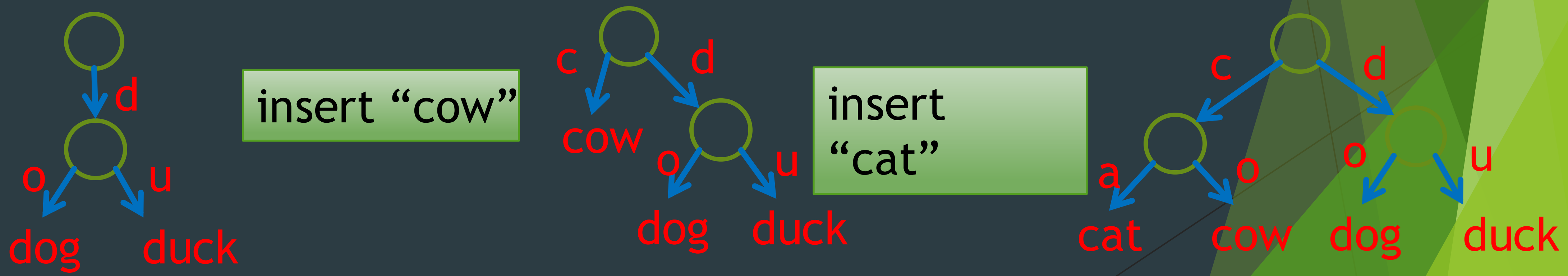


search “monkey”

search “cat”

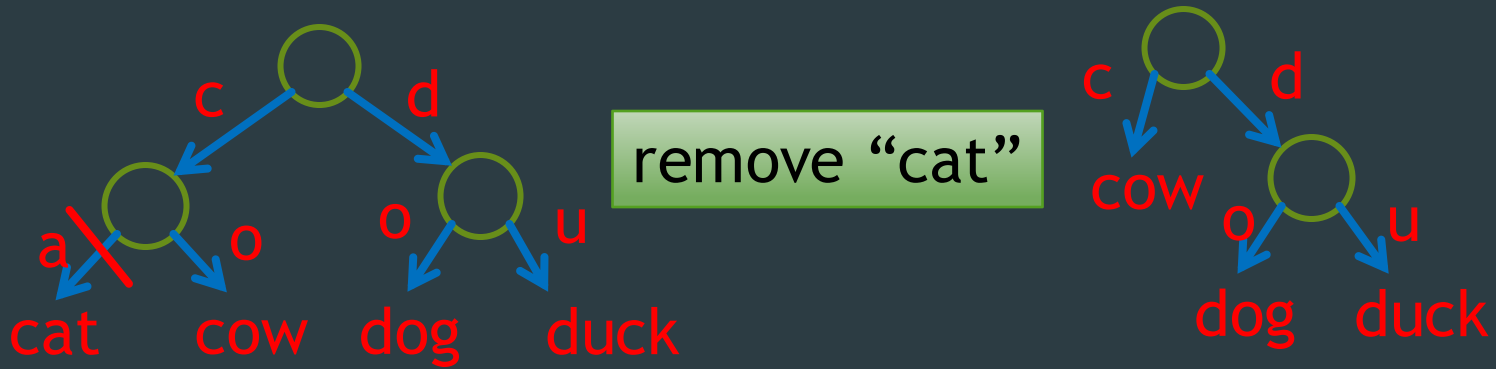
Trie Insertion

- Follow the search path, starting from the root.
- If a new branch is needed, add it.
- When the search leads to a leaf, a conflict occurs. We need to branch.
  - Use the next symbol in the key
  - The originally-unique word must be moved to lower level



Trie Removal

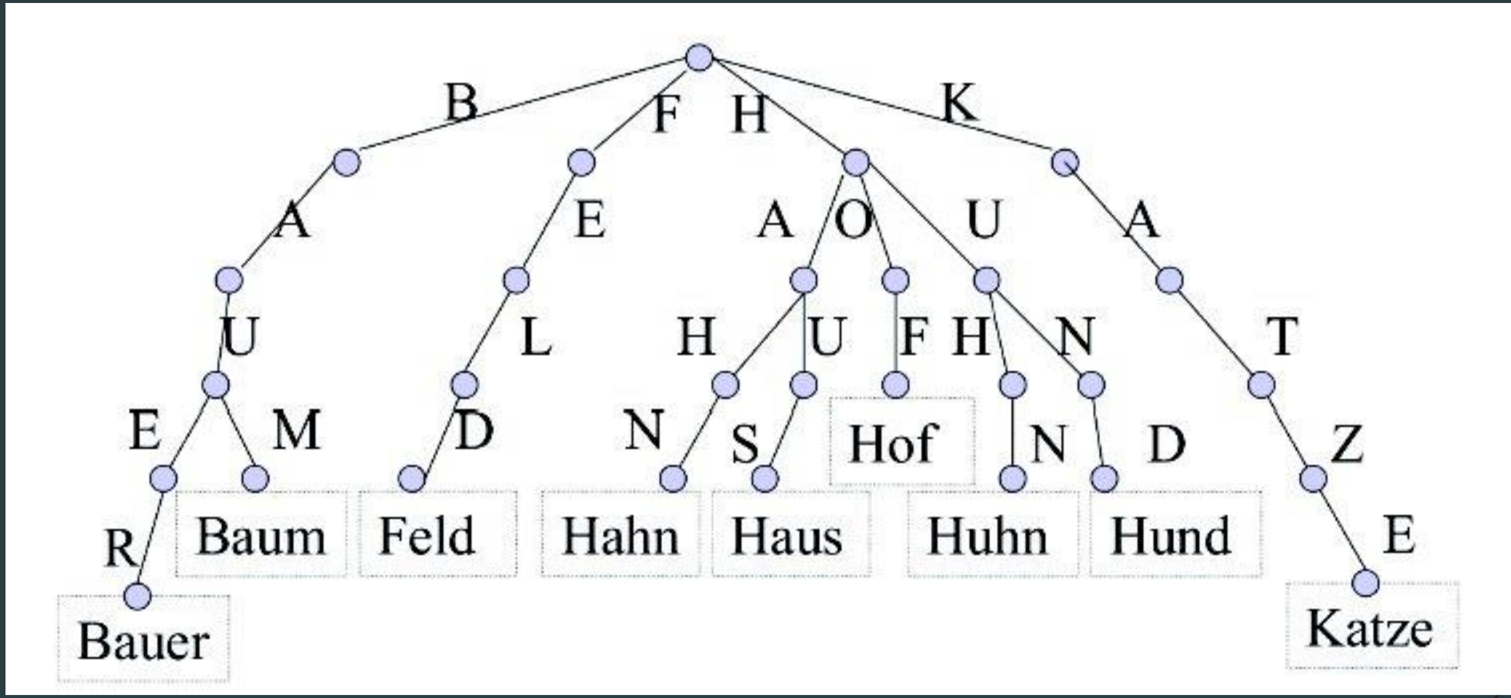
- The key to be removed is always at the leaf.
- After deleting the key, if the parent of that key now has only one child *C*, remove the parent node and move key *C* one level up.
  - If key *C* is the only child of its new parent, repeat the above procedure again.



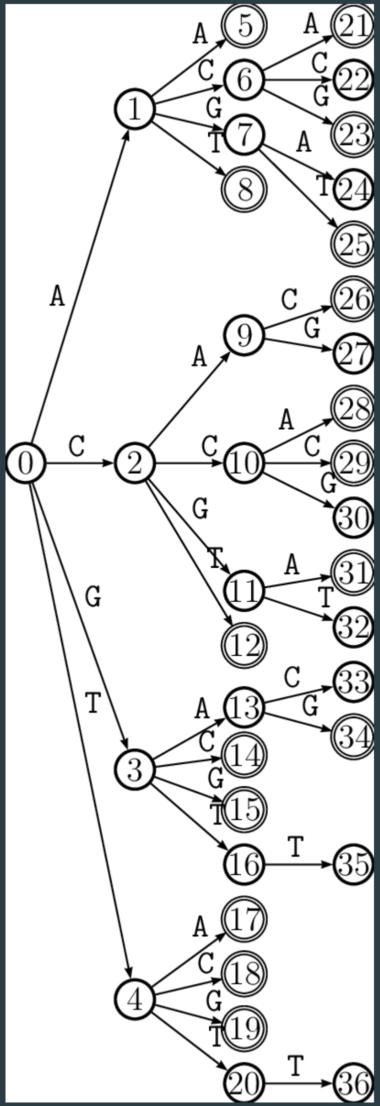
Time Complexity of Trie

- In the worst case, inserting or finding a key that consists of k symbols is $O(k)$.
  - This does not depend on the number of keys *N*.
  - Comparison: storing 32 integers in the range [0, 127] using a trie versus using a BST. What are heights in the worst case? BST: 32; Trie: 7
- Sometimes we can access records even [faster].
  - A key is stored at the depth which is enough to distinguish it with others.
  - For example, in the previous example, we can find the word "duck" with just "du".

Use Case 1 – Spell Checking



Use Case 2 – Human Genome



Exercise 1

Problem 208. Implement Trie (Prefix Tree)

Search