CMPE 493
INTRODUCTION TO
INFORMATION RETRIEVAL

Dictionaries

Department of Computer Engineering, Boğaziçi University
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Inverted index

For each term t, we store a list of all documents that contain t.

BRUTUS	⟶	1	2	4	11	31	45	173	174
CAESAR	⟶	1	2	4	5	6	16	57	132	...
CALPURNIA	⟶	2	31	54	101				
⋮									

dictionary — postings

Dictionaries

- The dictionary is the data structure for storing the term vocabulary.
- Term vocabulary: the data
- Dictionary: the data structure for storing the term vocabulary

A naïve dictionary

- An array of struct:

term	document frequency	pointer to postings list
a	656,265	⟶
aachen	65	⟶
. . .	. . .	. . .
zulu	221	⟶
char[20]	int	Postings *
20 bytes	4/8 bytes	4/8 bytes

- How do we store a dictionary in memory efficiently?
- How do we quickly look up elements at query time?

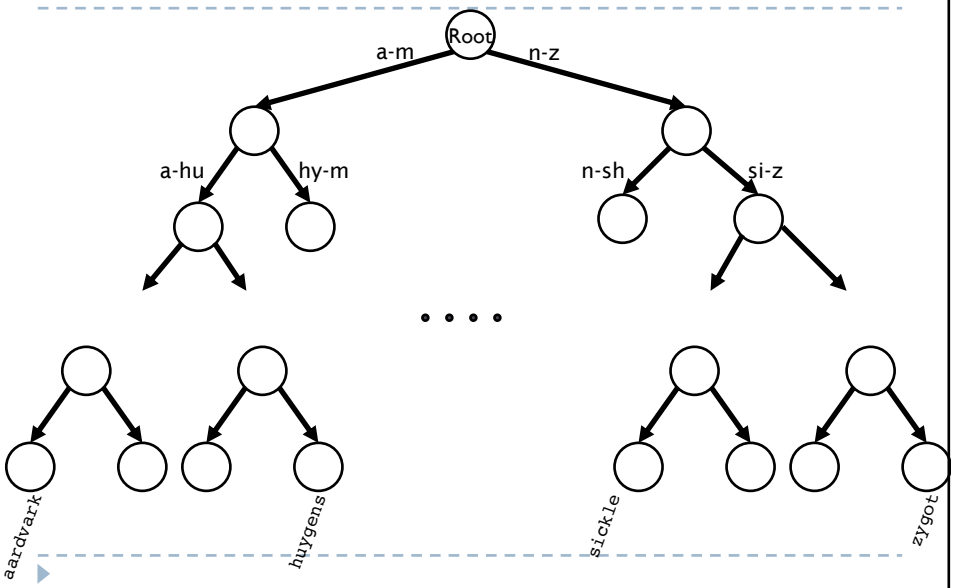
Data structures for looking up term

- Two main classes of data structures:
  - hashes
  - trees
- Some IR systems use hashes, some use trees.

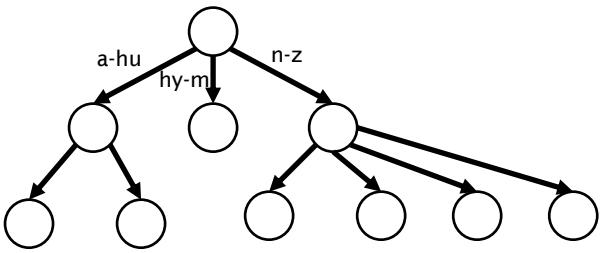
Hashes

- Each vocabulary term is hashed into an integer.
- Try to avoid collisions
- At query time, do the following: hash query term, resolve collisions, locate entry in fixed-width array
- Pros: Lookup in a hash is faster than lookup in a tree.
  - Lookup time is constant.
- Cons
  - no way to find minor variants (*resume* vs. *résumé*)
  - no prefix search (all terms starting with *automat*)
  - need to rehash everything periodically if vocabulary keeps growing

Tree: binary tree



Tree: B-tree



- Definition: Every internal node has a number of children in the interval [*a*,*b*] where *a, b* are appropriate natural numbers, e.g., [2,4].

Trees

- Simplest: binary tree
- More usual: B-trees
- Trees require a standard ordering of characters and hence strings … but we standardly have one
- Pros:
  - Solves the prefix problem (terms starting with *hyp*)
- Cons:
  - Slower: O(log *N*) [and this requires *balanced* tree]
  - Rebalancing binary trees is expensive
    - But B-trees mitigate the rebalancing problem

Trie (Keyword Tree)

- A tree-based data structure, name comes from "retrieval"
- Each node stores a letter from the alphabet and each word corresponds to a path in this tree.
- Can be used to store the Dictionary.
  - Mark nodes corresponding to end of words and store link (pointer) to the associated postings.
  - Can be used to answer prefix searches such as in Auto-complete

Creating a Trie

Root

Dictionary

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Dictionary

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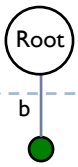

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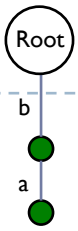

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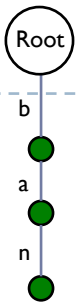

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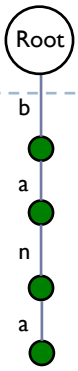

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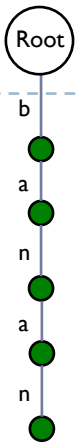

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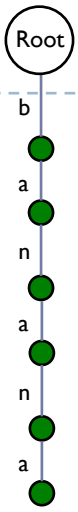

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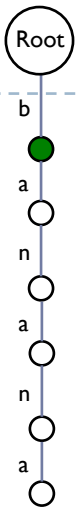

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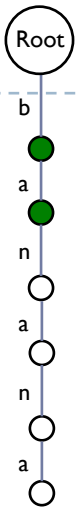

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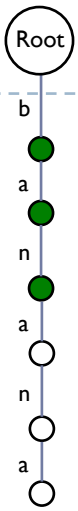

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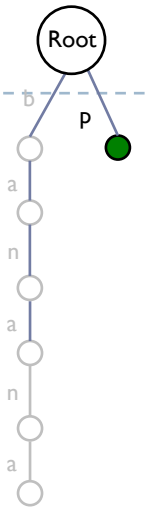

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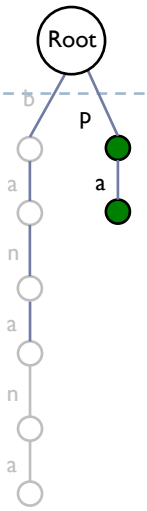

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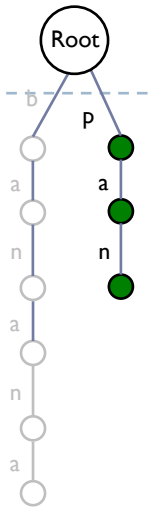

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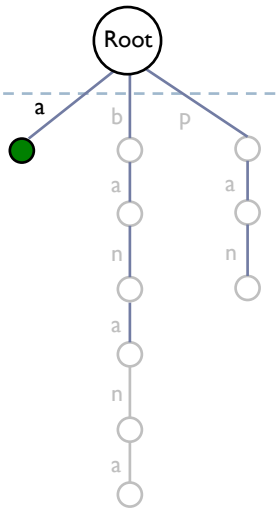

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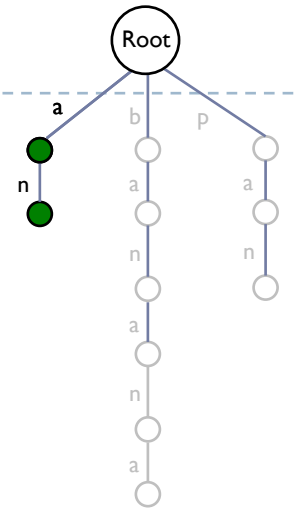

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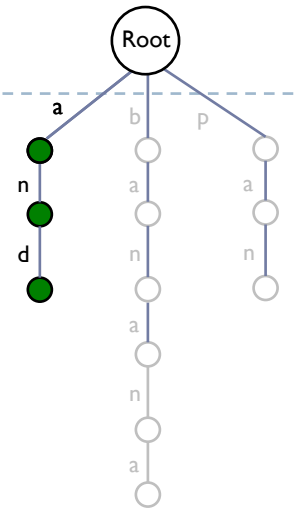

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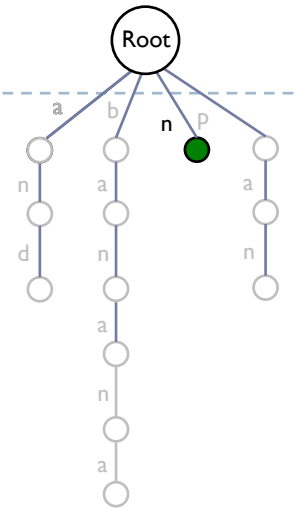

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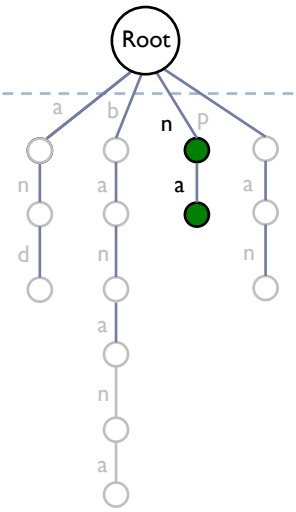

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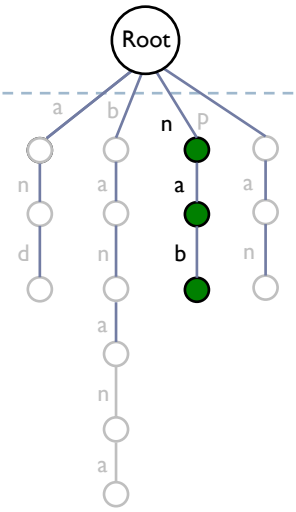

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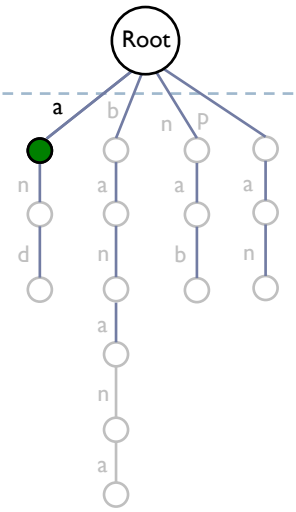

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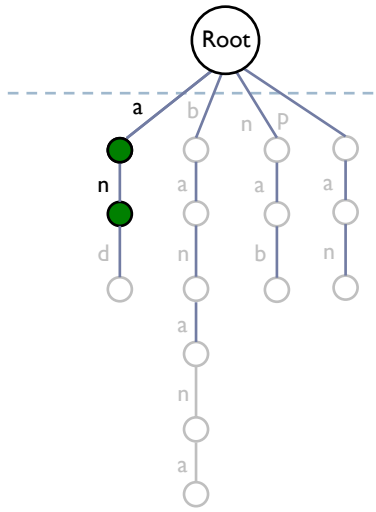

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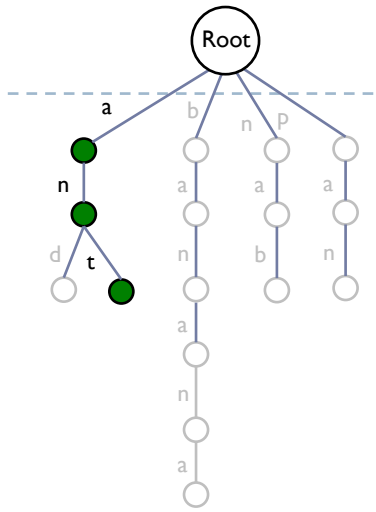

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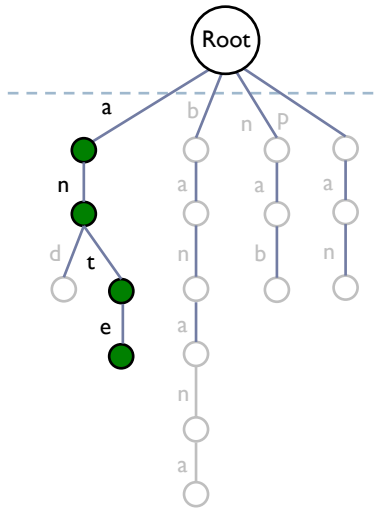

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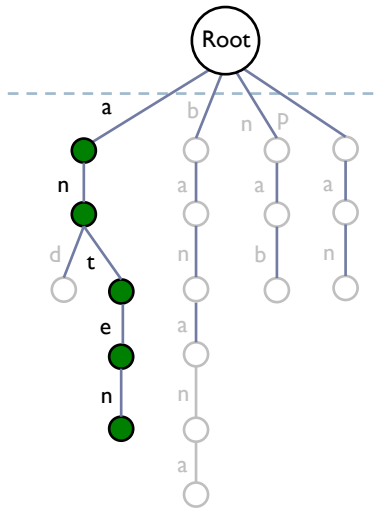

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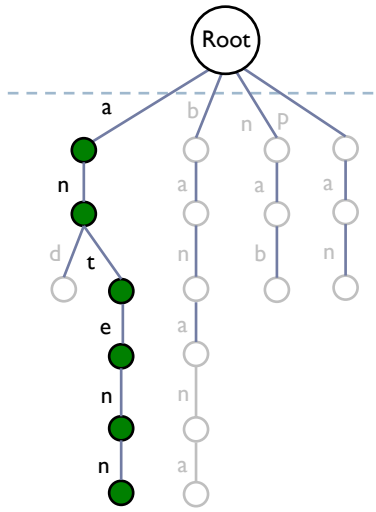

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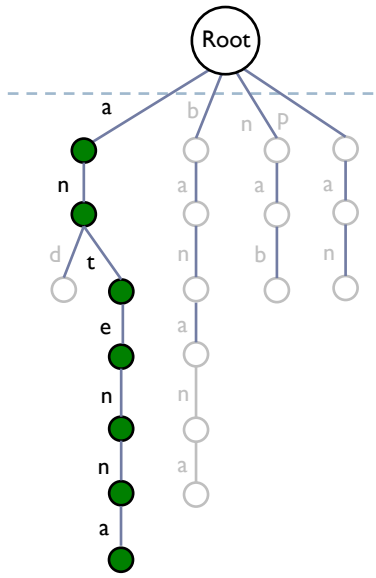

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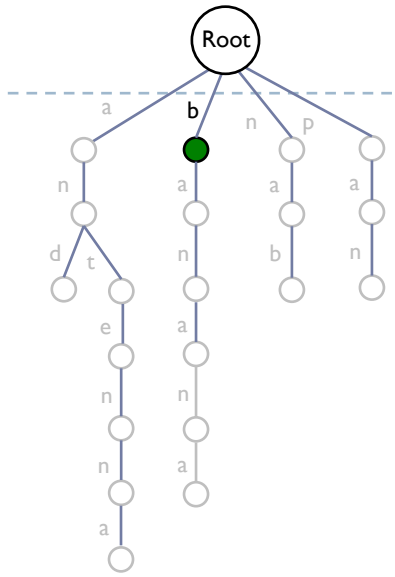

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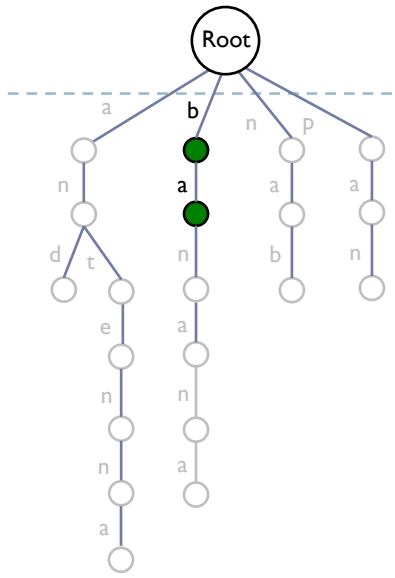

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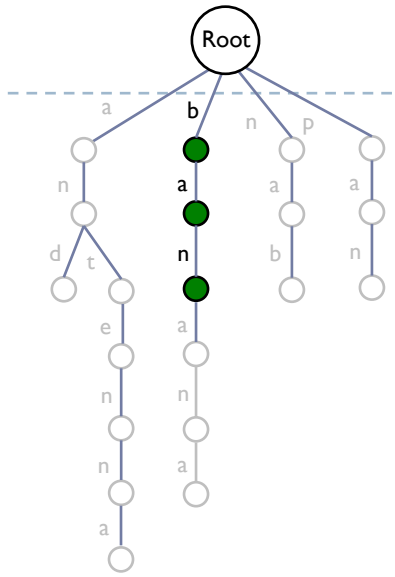

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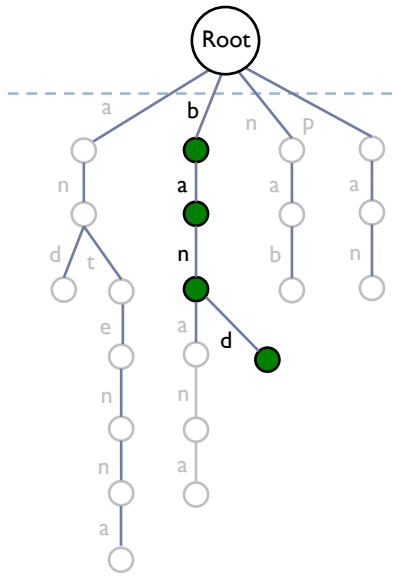

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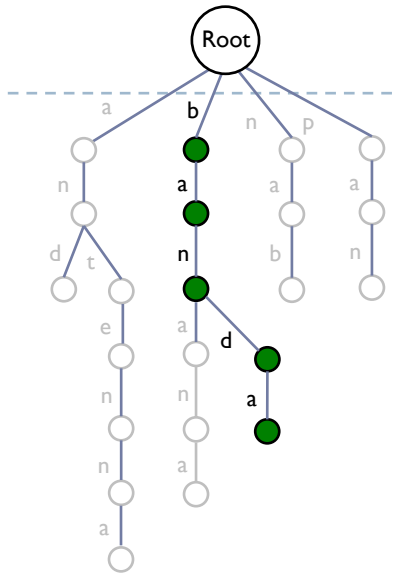

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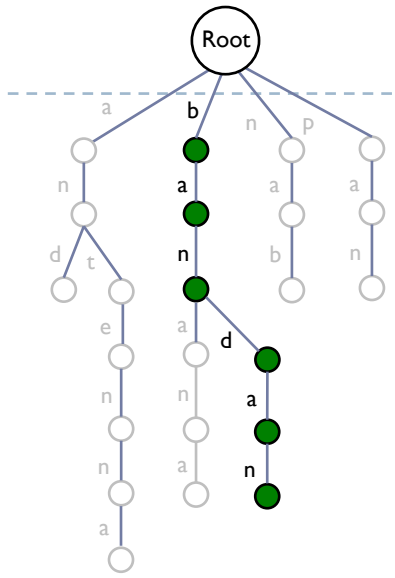

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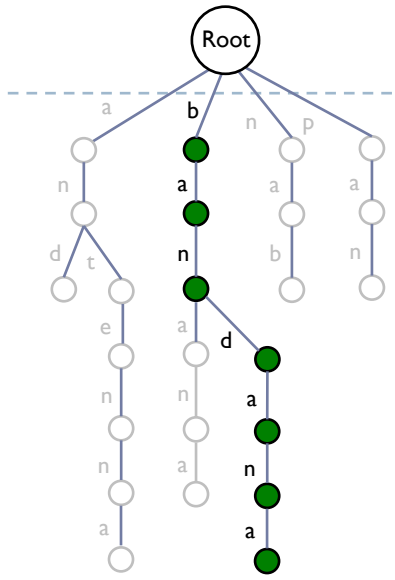

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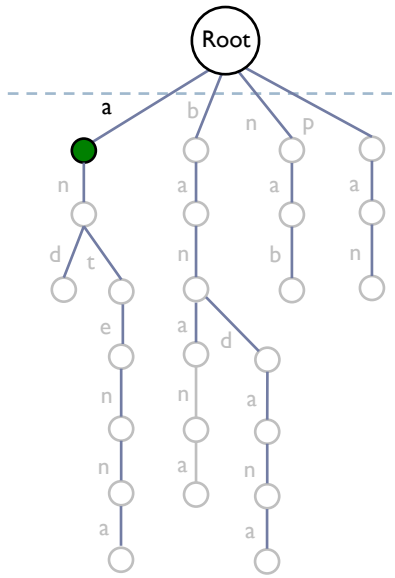

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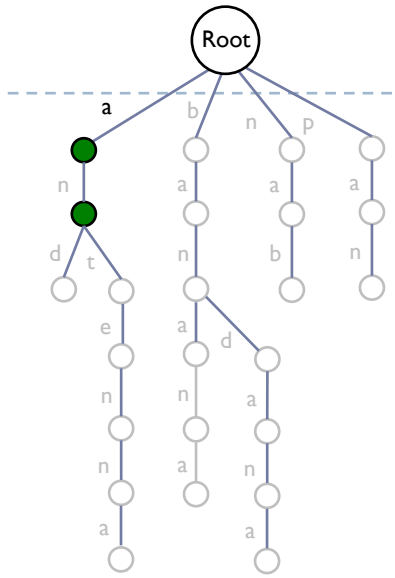

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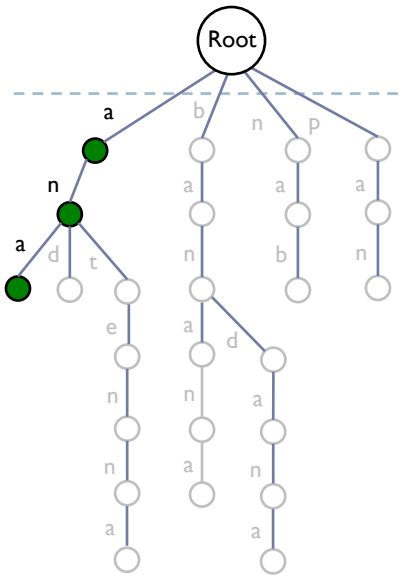

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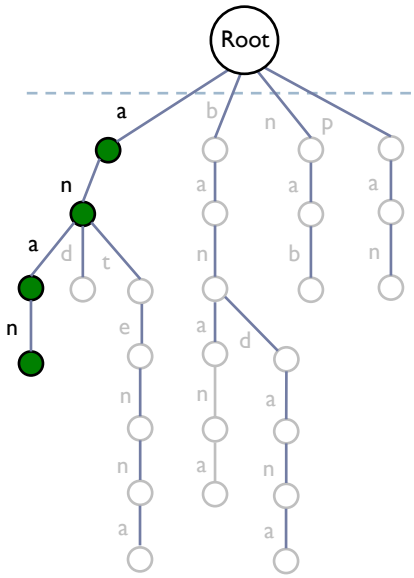

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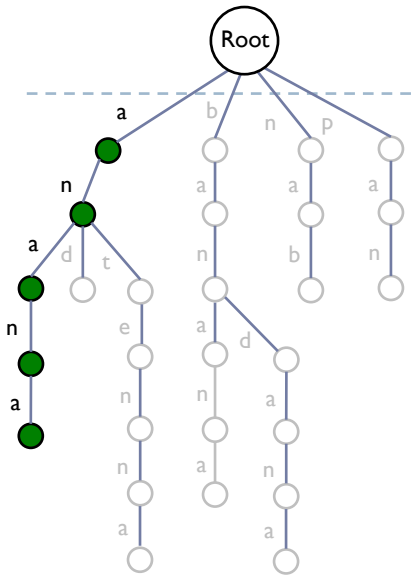

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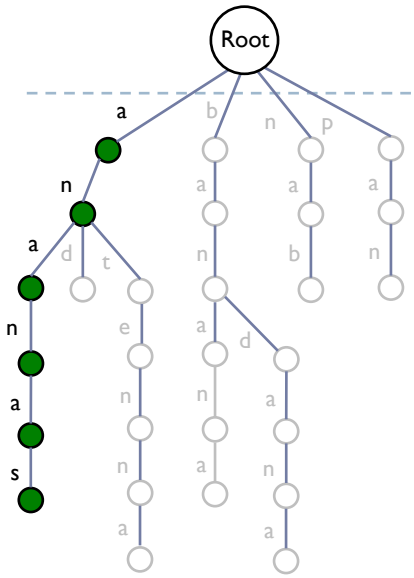

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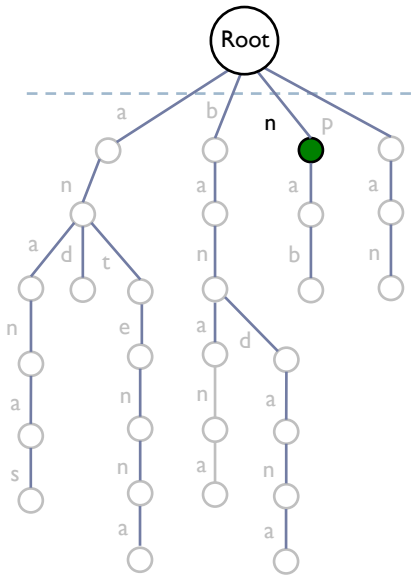

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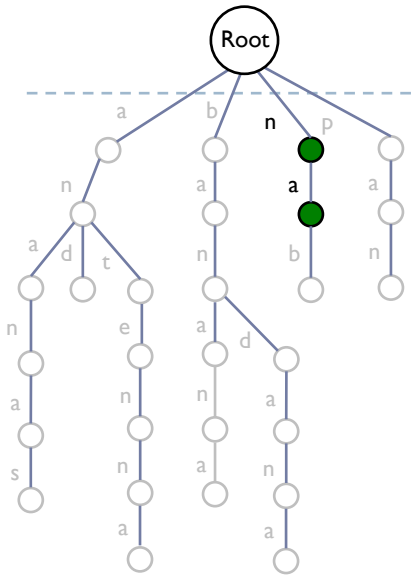

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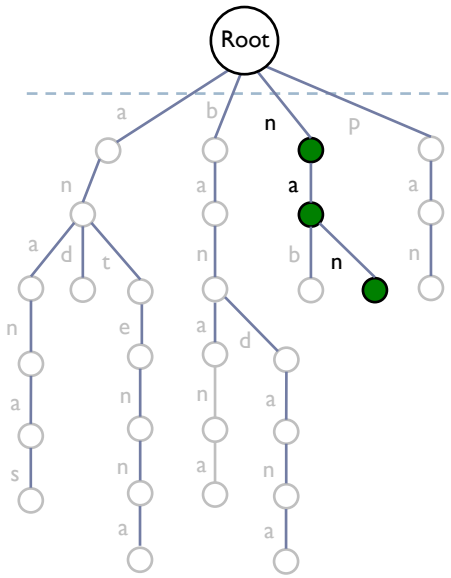

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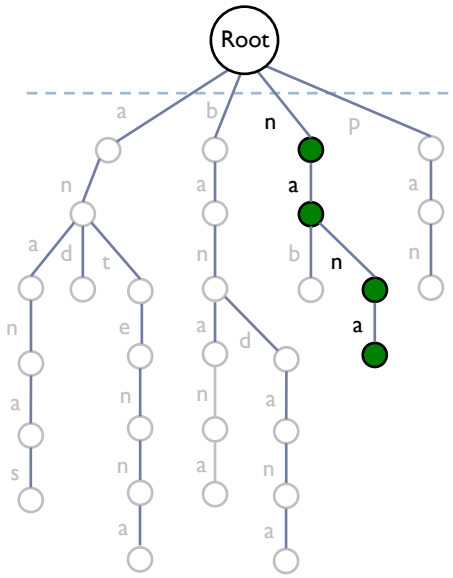

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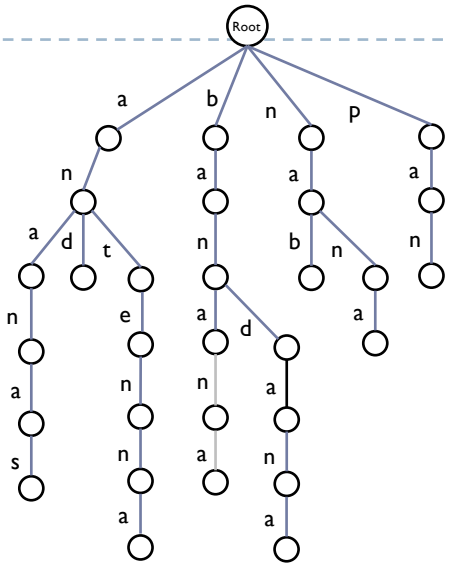
Complexity of Trie Construction:

- O(|*Dictionary*|) or O(*m***N*)
  - *m* longest word in the Dictionary
  - *N* total number of words in the Dictionary

Searching in a Trie

Search for: nar



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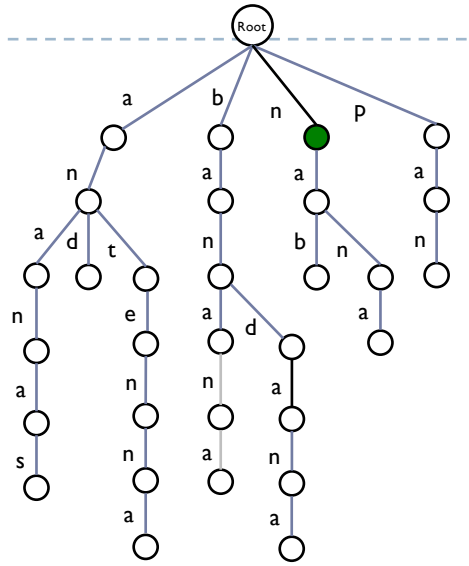
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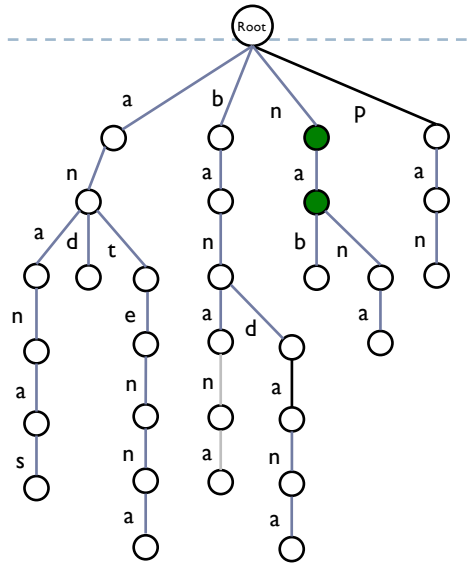
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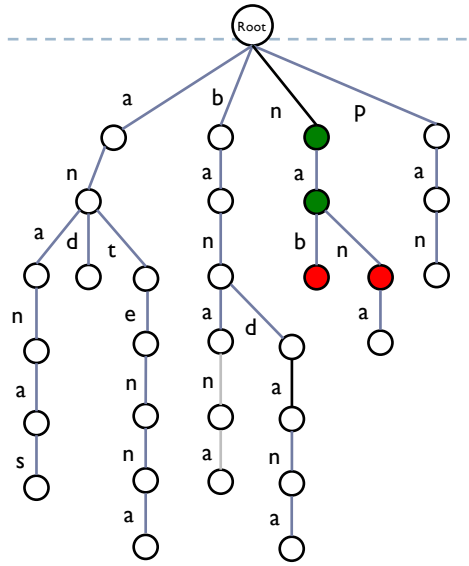
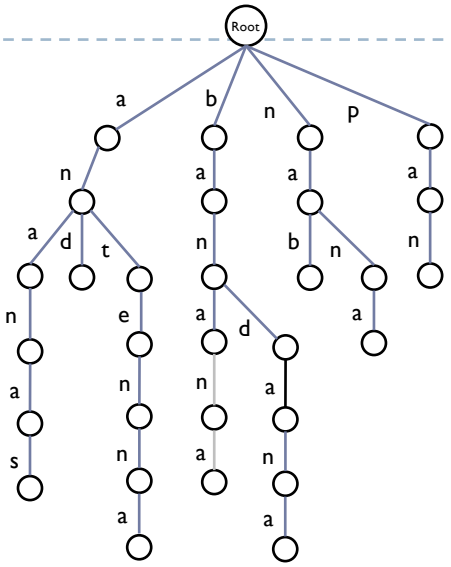


No match.

Search for: and



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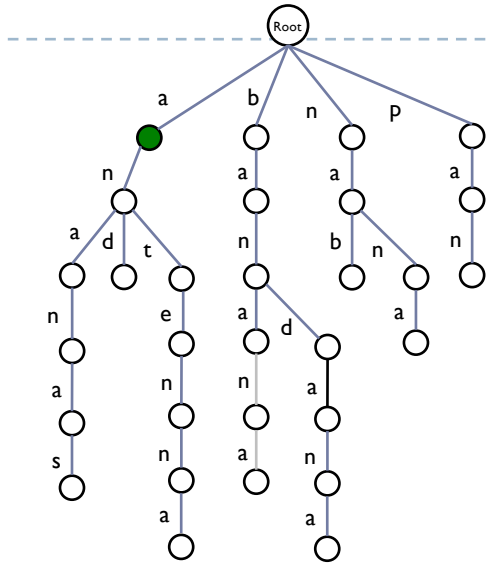
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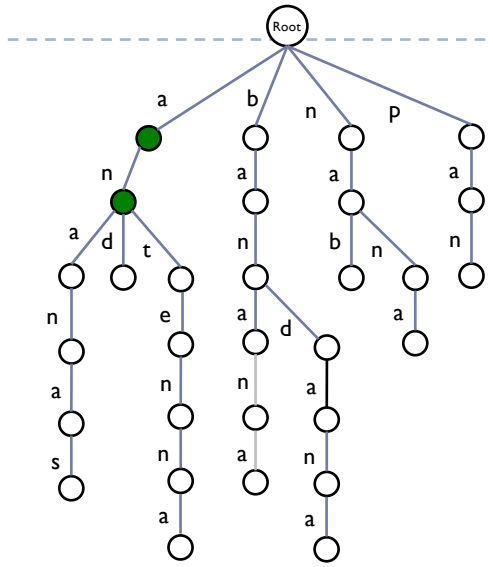
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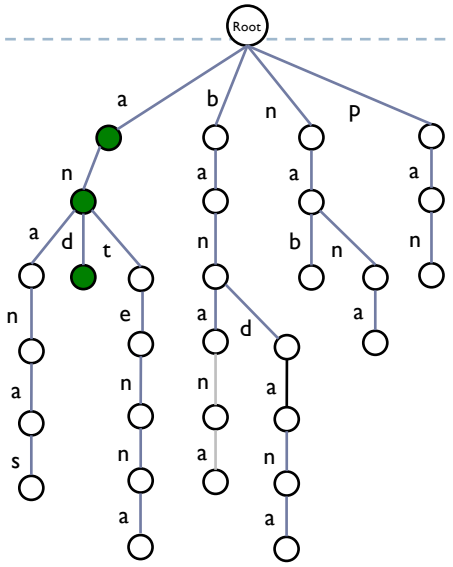
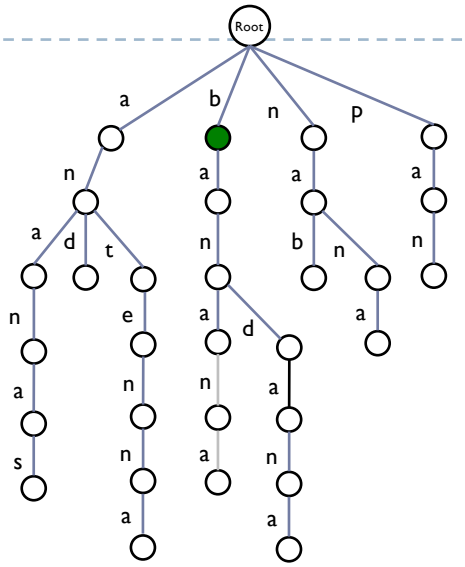
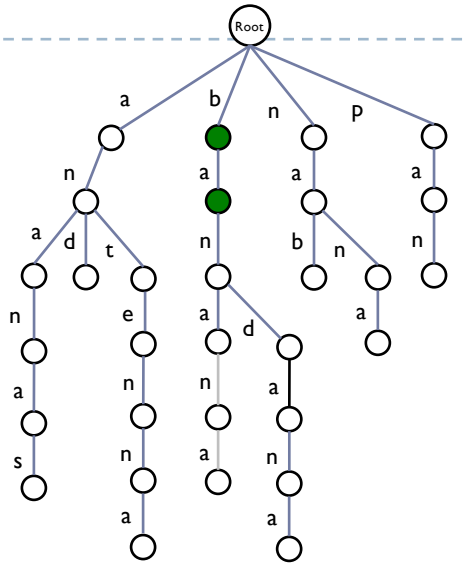


Match found, retrieve the postings for the keyword.

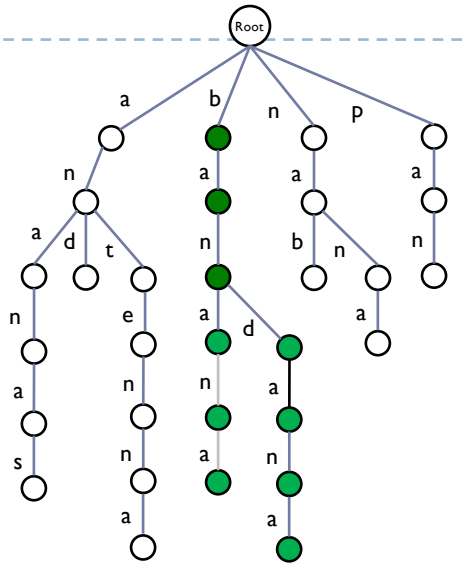
prefix search: ban*



ban*

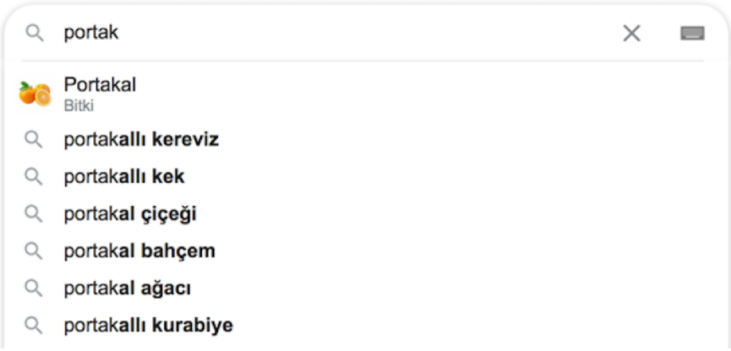


ban*



Matches:
ban
banana
bandana

Auto-Complete



Complexity of Trie Matching:

- Trie Construction: O(|*Dictionary*|) or O(*m***N*)
  - *m* longest word in the Dictionary
  - *N* total number of words in the Dictionary
- Search for keyword: O(*m*)
  - *m* longest word in the Dictionary

References

- *Introduction to Information Retrieval*, chapter 3
  - http://nlp.stanford.edu/IR-book/information-retrieval-book.html
- Some slides adapted from Dr. Christopher Manning and Dr. Pandu Nayak
- Trie slides adapted from the lecture notes of Bioinformatics Algorithms: An Active Learning Approach, Volume 2, Chapter 9.