Using Abstractions: Breadth-First Search

How can we use the unique properties of different abstractions to solve problems?

Examples of interesting problems to solve using ADTs

- Simulate potential impacts of flooding on a topographical landscape (how does water flow outwards from a source and settle into the surrounding areas)
- Generate simulated text in the style of a certain author. Similarly, do textual analysis to determine who the author of a provided piece of text was.
- Spell check and autocomplete for a word document editor
- Manage information about the natural landmarks and state parks in California to help tourists plan their trip to the state
- Develop a ticketing management system for Stanford Stadium
- Aggregate and analyze reviews for an online shopping website
- Solve fun puzzles

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Word Ladders

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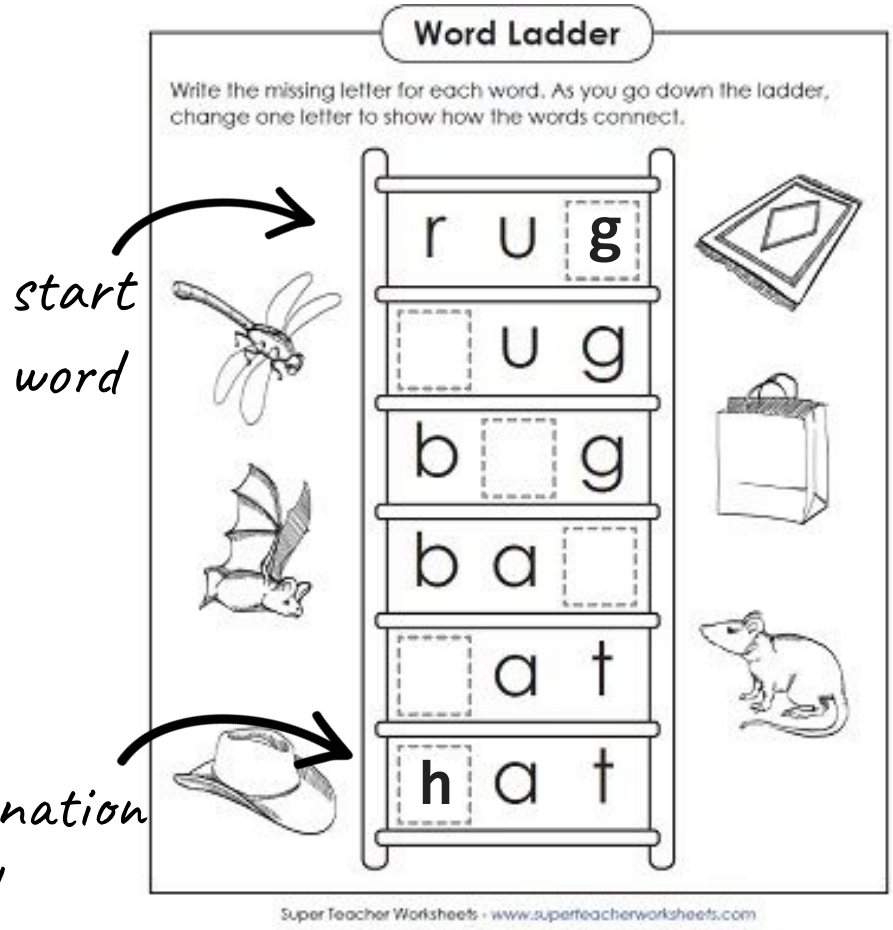

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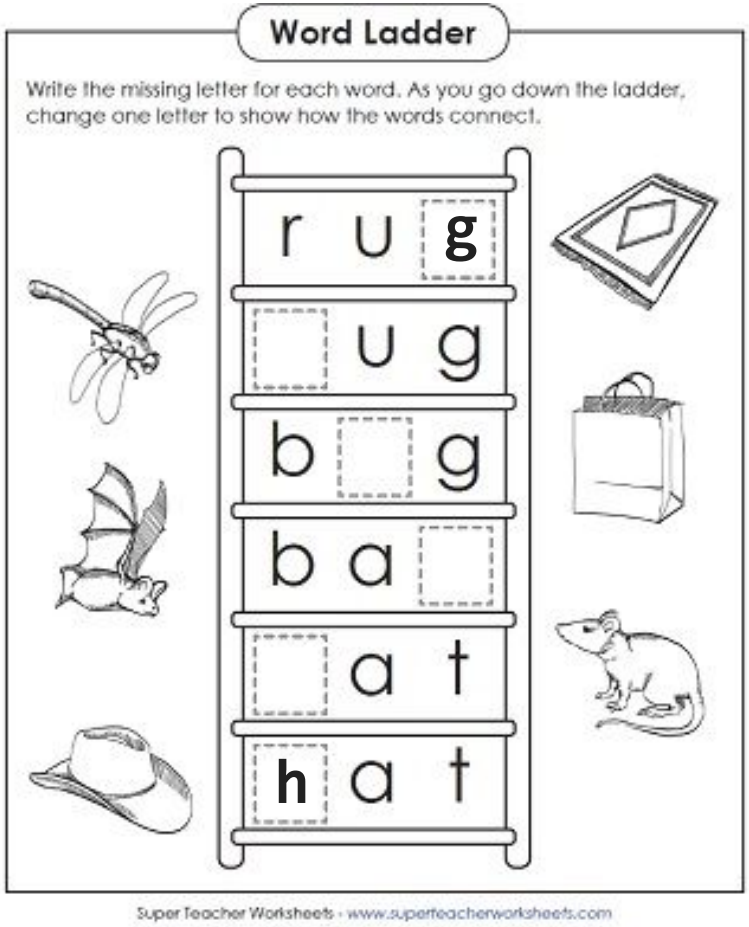

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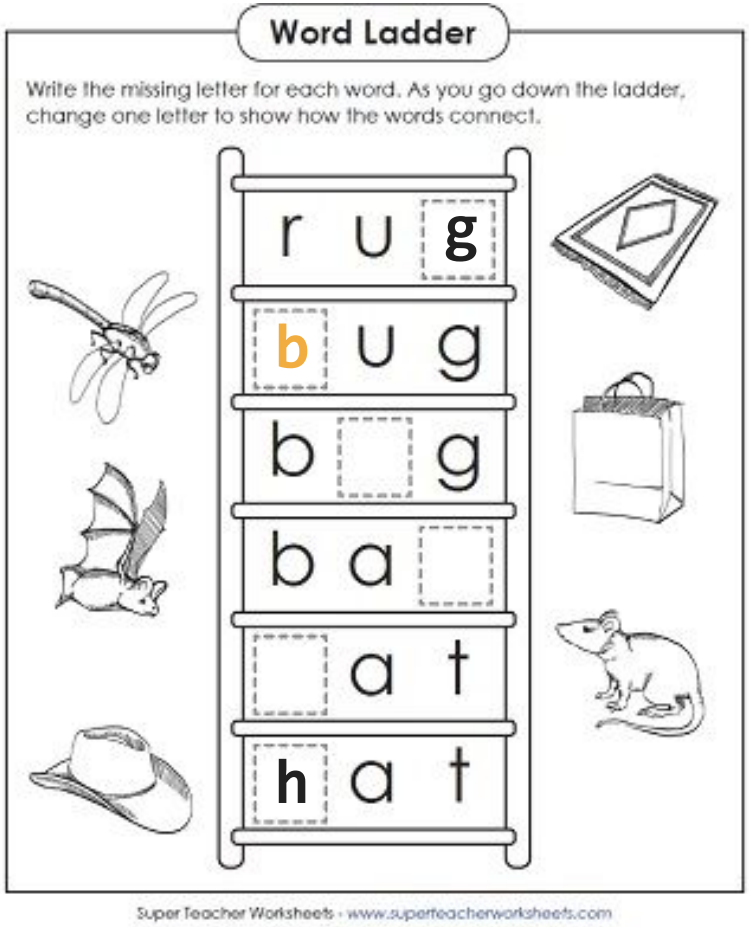

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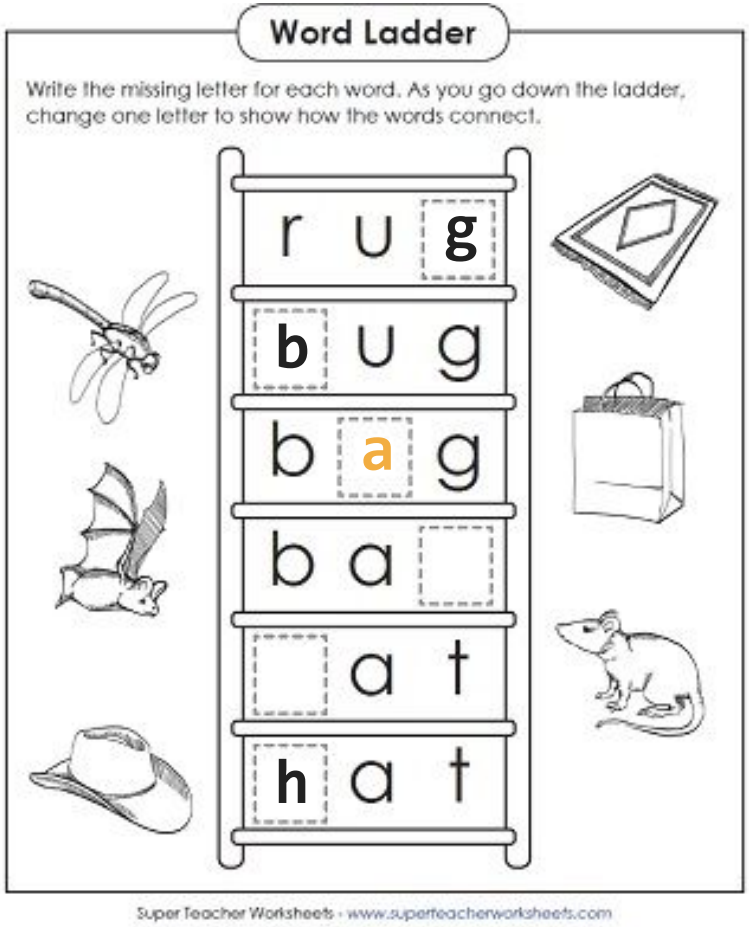

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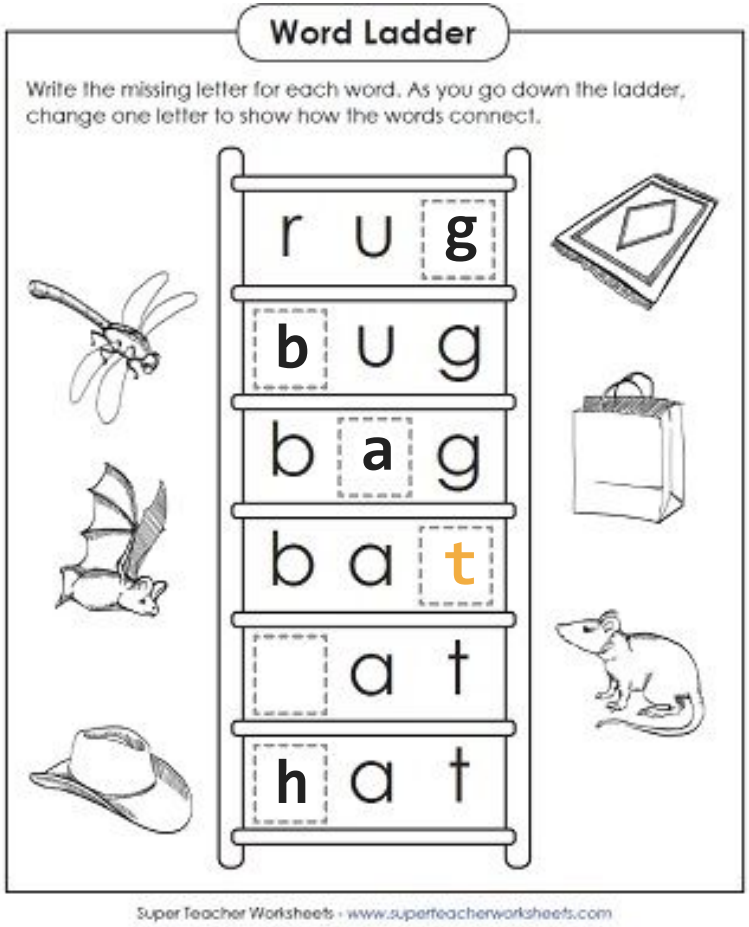

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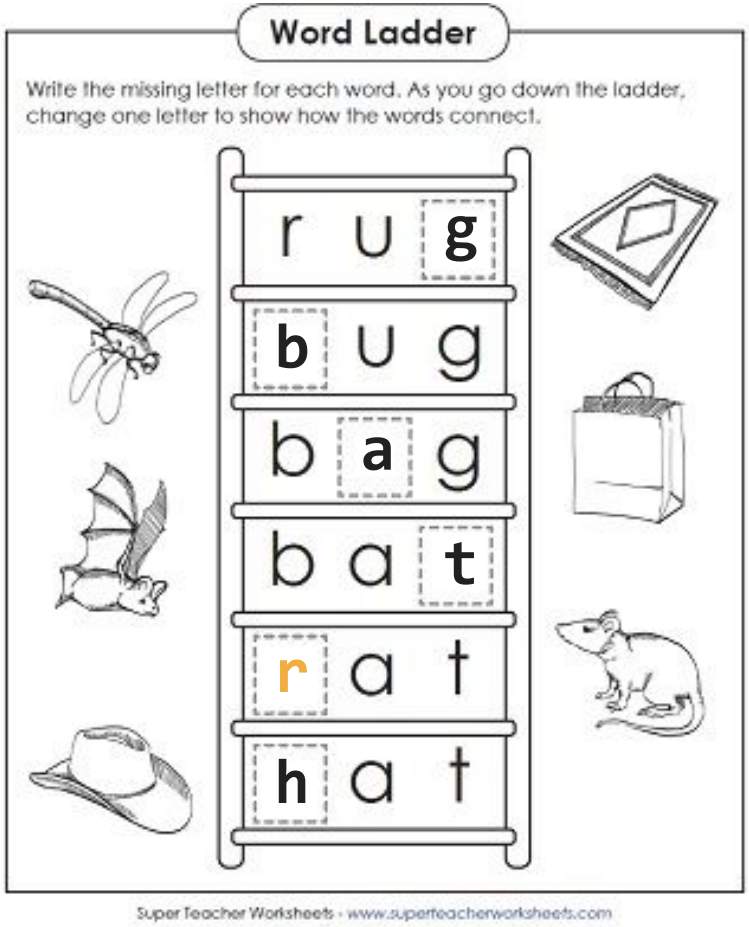

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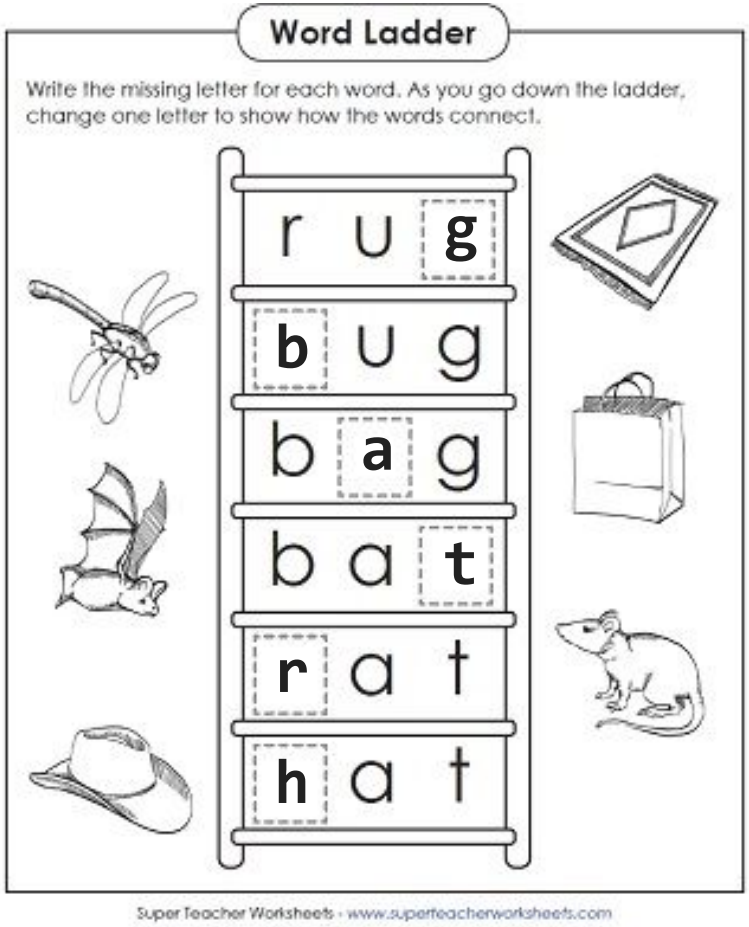

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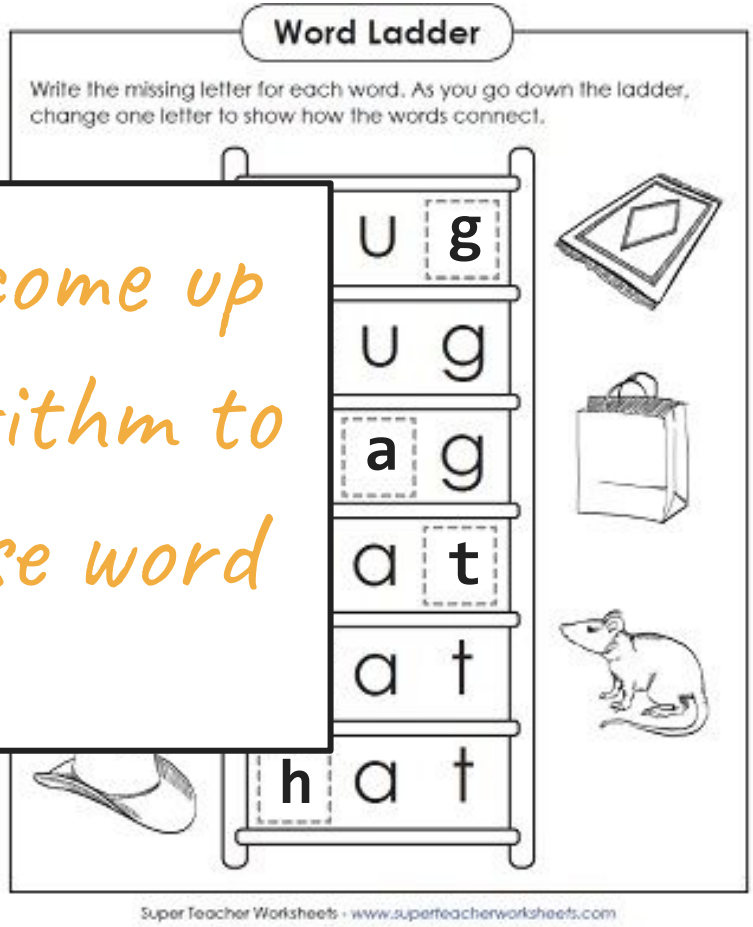
How can we come up with an algorithm to generate these word ladders?



Word Ladder Generation First Attempt

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- Given a start word and a target word, a natural place to start would be to model how a human might attempt to solve this problem
  - Start at the start word
  - Make an educated guess about what letter to change first
  - Modify that letter to get to a new English word
  - From there, make another educated guess about which letter to change and modify that letter
  - Keep repeating this process until you reach the target word (unlikely) or hit a dead end (likely)
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- What are the issues with this approach?
  - Requires intuition – does a computer have intuition?
  - Unorganized – no organized strategy for the exploration
  - No guarantee that you'll ever find a solution!

Breadth-First Search

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- **Important observation: In order to keep our search organized, we first explore all word ladders of "length" 1 before we explore any word ladders of "length" 2, and so on.**

BFS Example

Breadth-First Search Example

- Let's try to apply this approach to find a word ladder starting at the word "map" and ending at the word "way"

Breadth-First Search Example

start: map
destination: way

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start: map
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0 steps away

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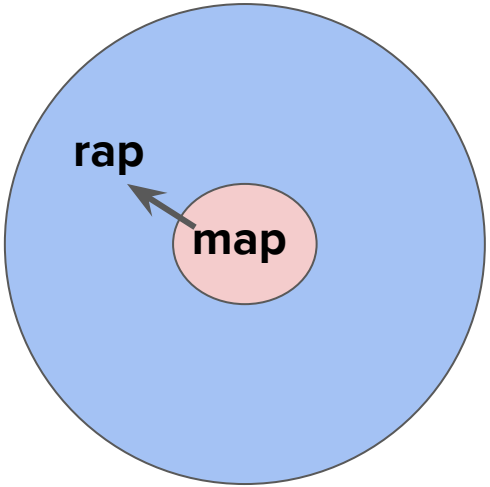

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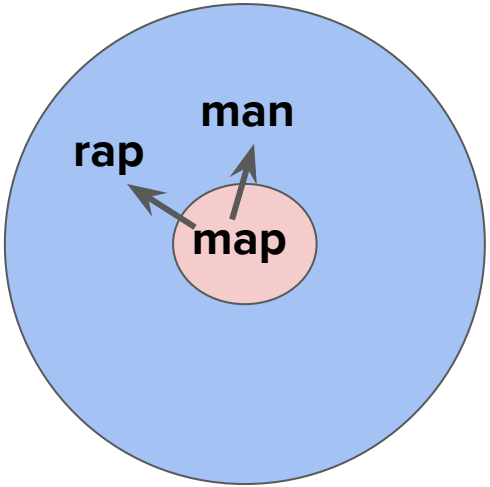

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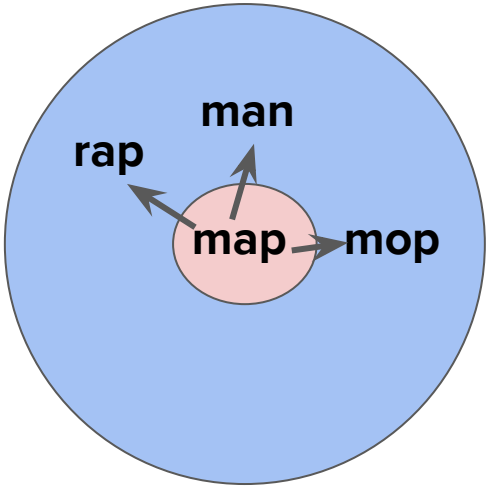

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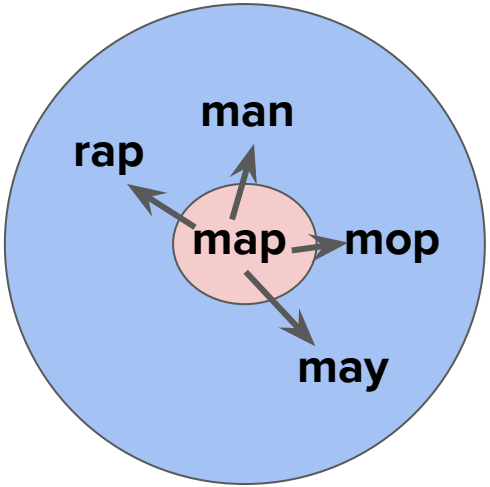

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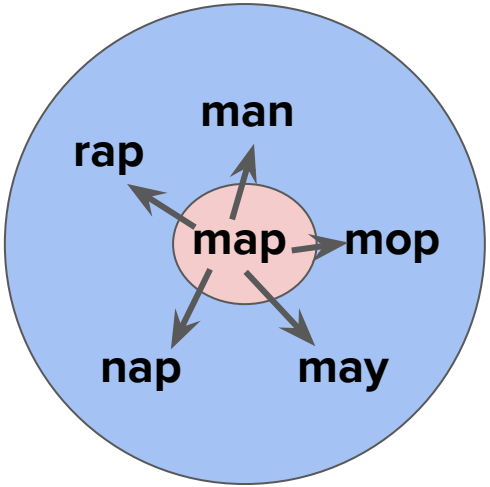

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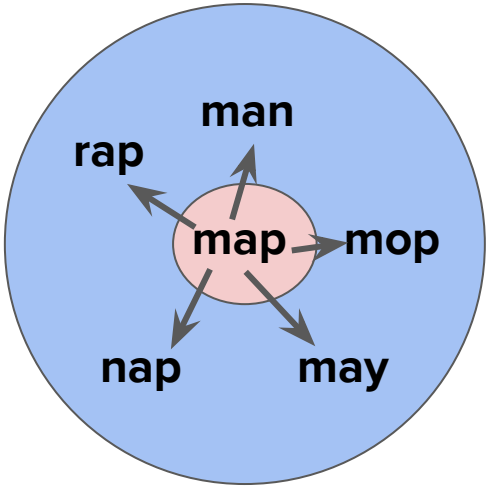

0 steps away
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Note: For the sake of brevity/demonstration, we will not enumerate all possible words that are 1 step away

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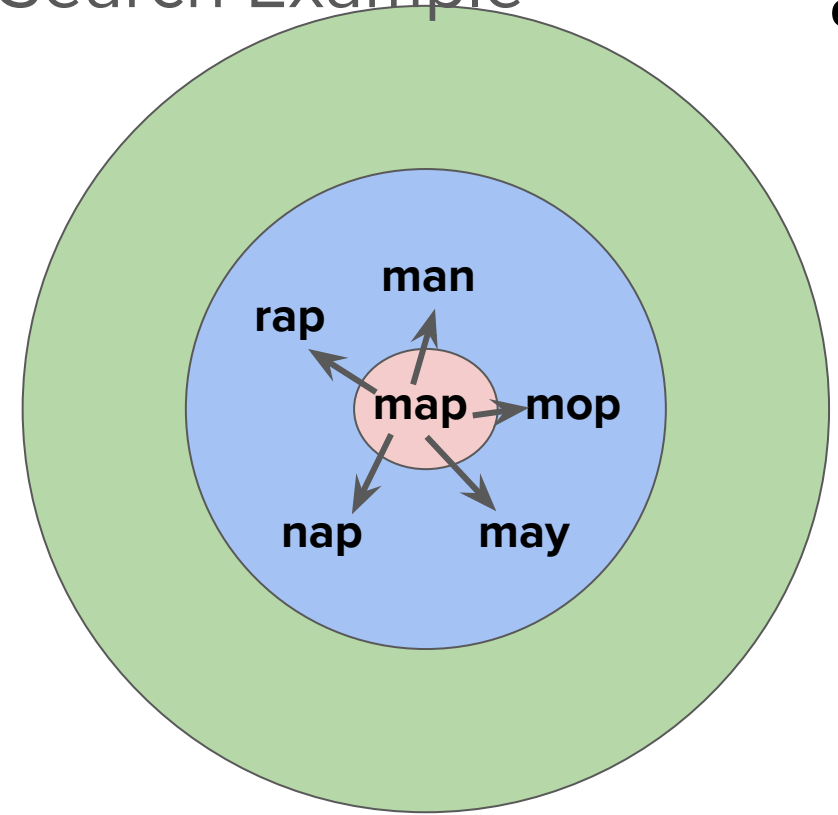

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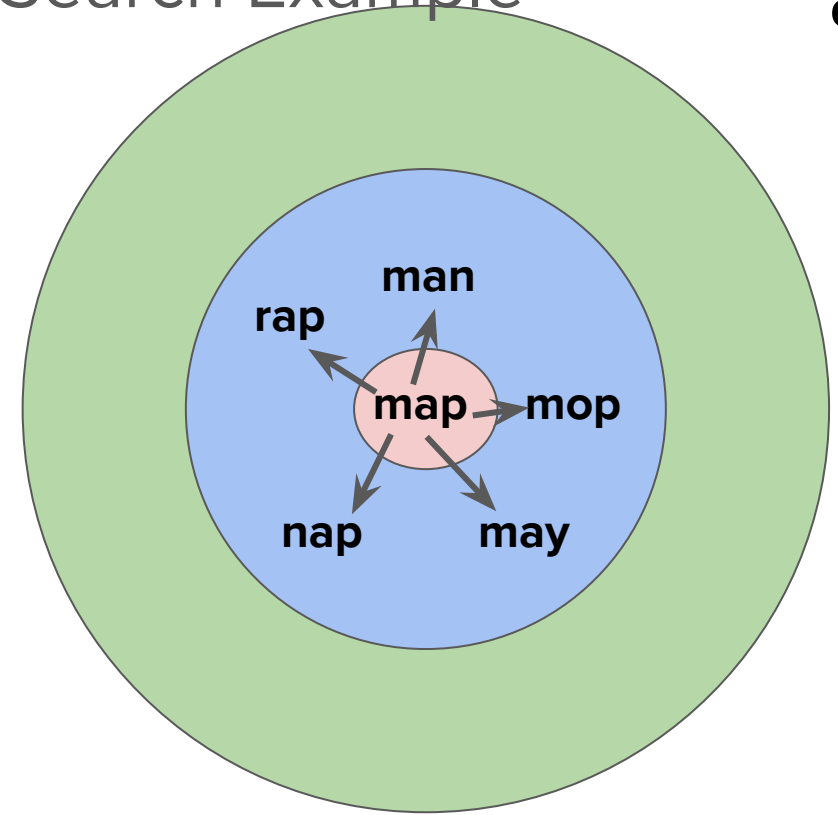

0 steps away
1 step away
2 steps away

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start: map
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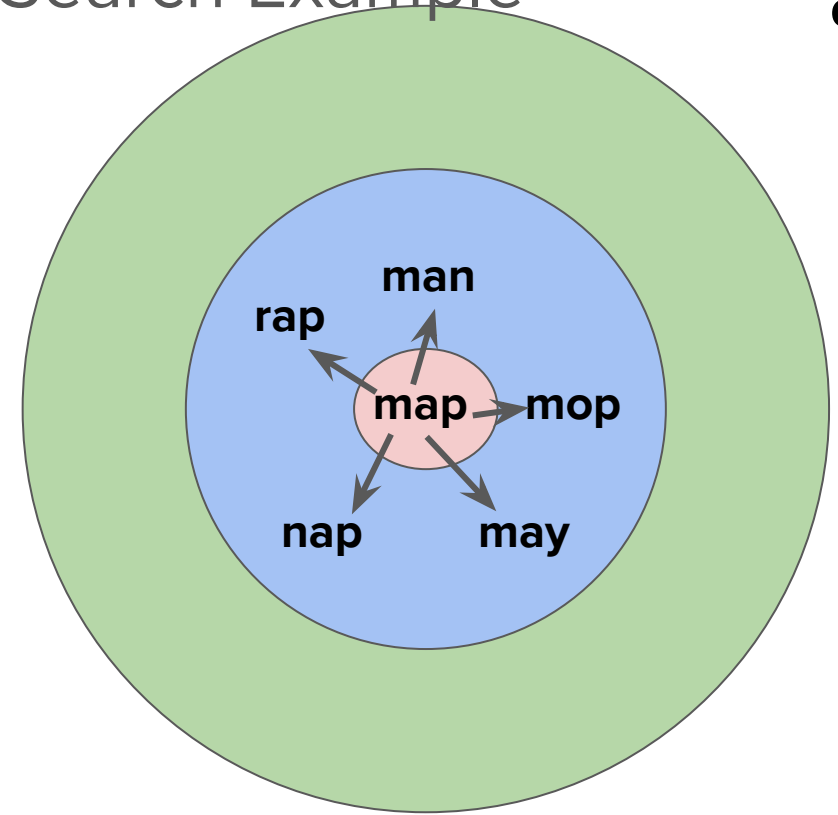

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Observation: 2 steps away from "map" is really just 1 step away from any of its neighbors

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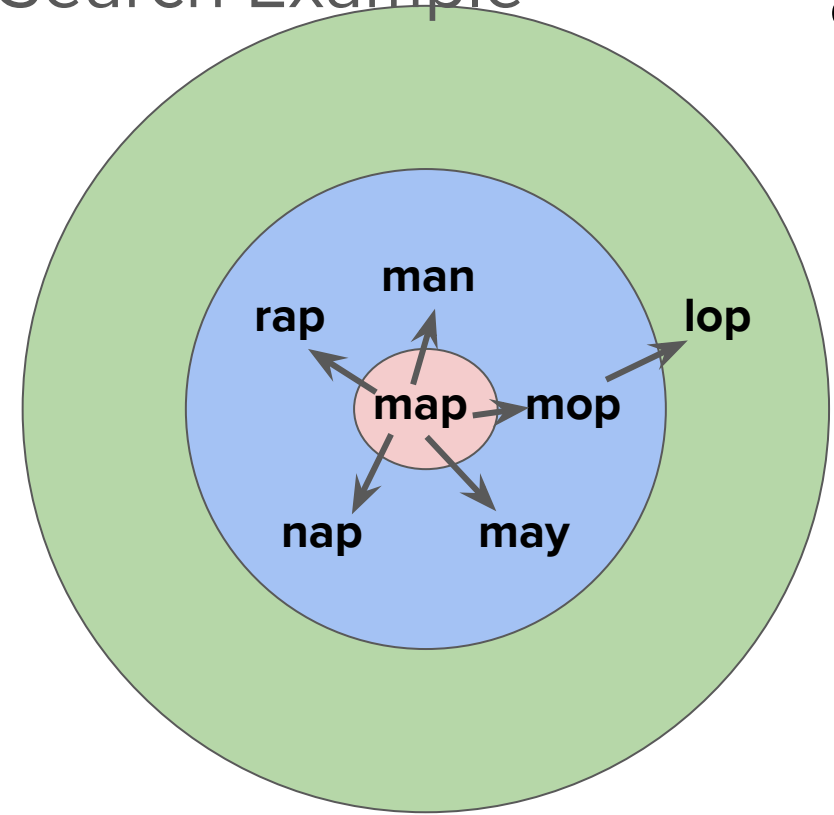

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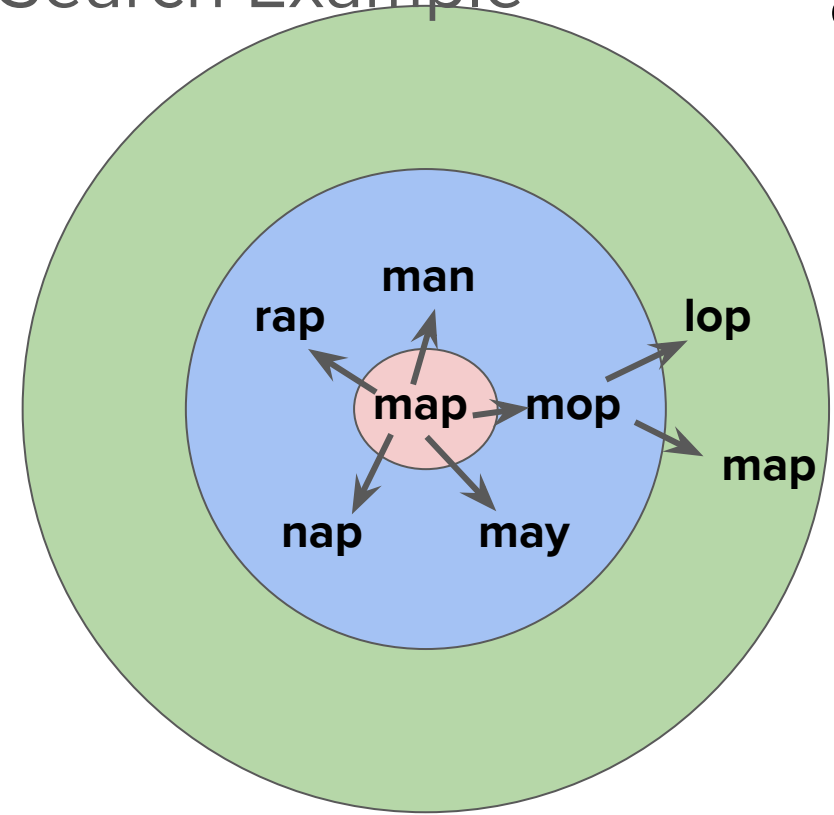

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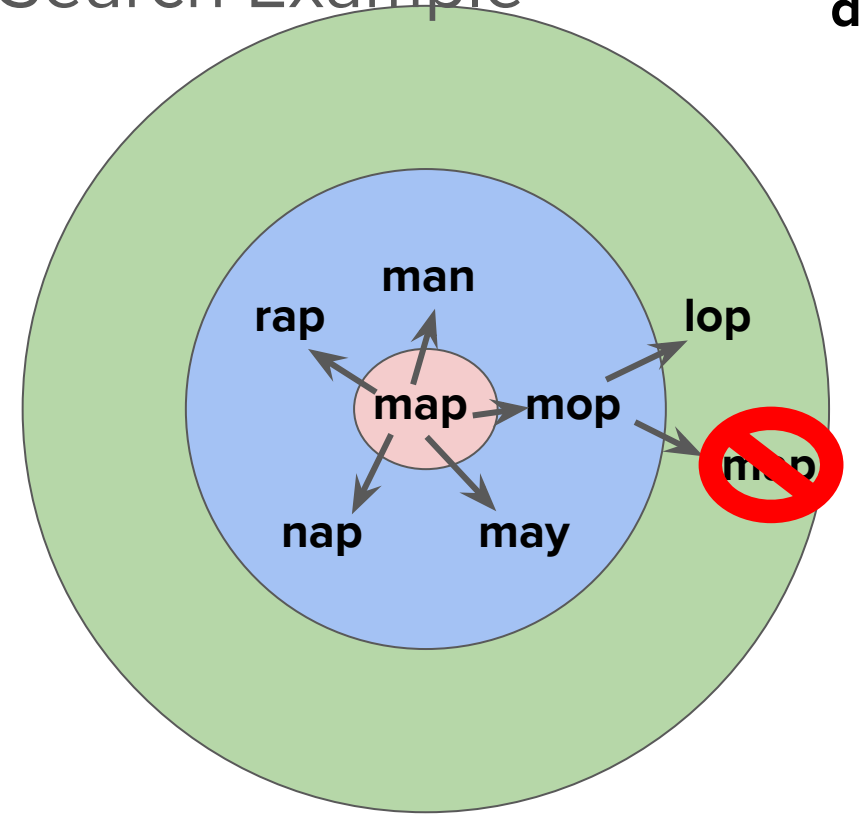

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Visiting a word we've already been at before is basically like going backwards in our search. We want to avoid this at all costs!

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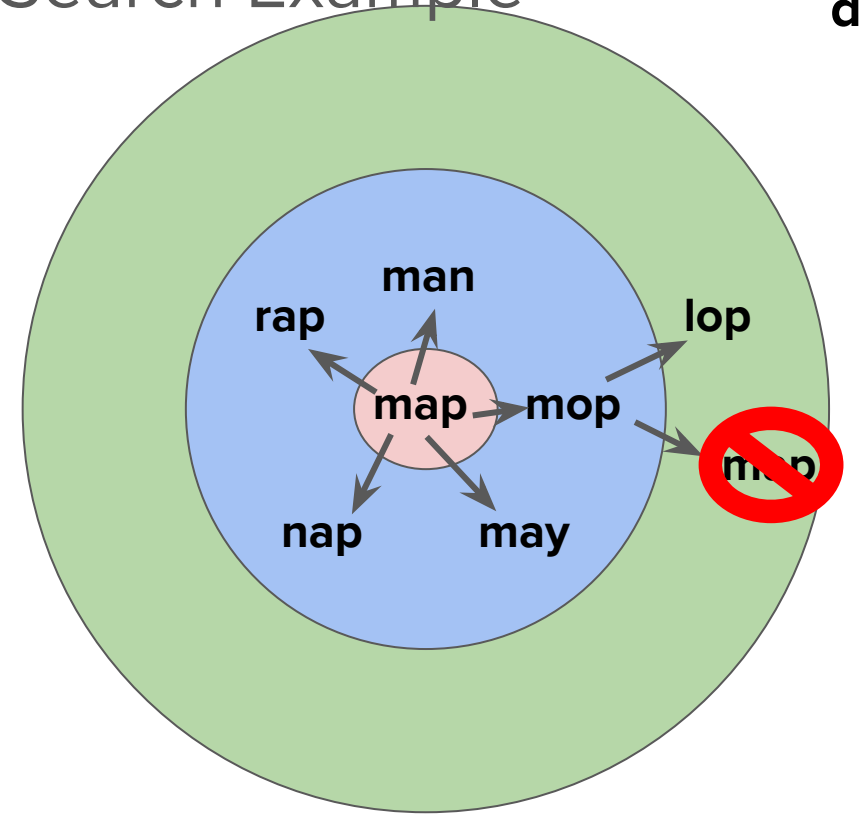

Idea: Keep track of a collection of visited words, and don't double visit

0 steps away
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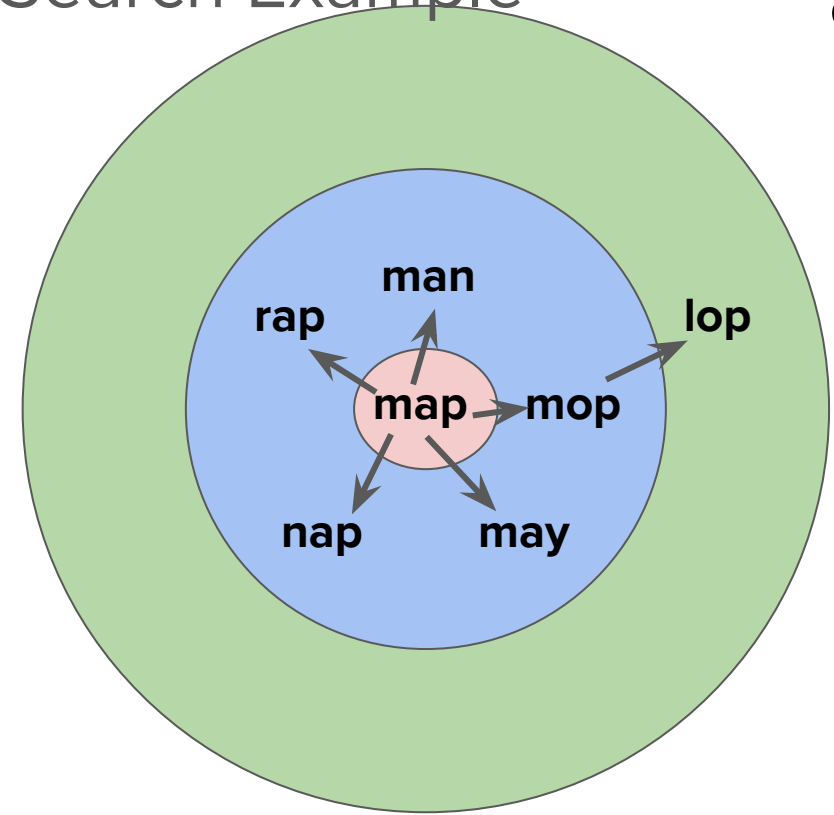

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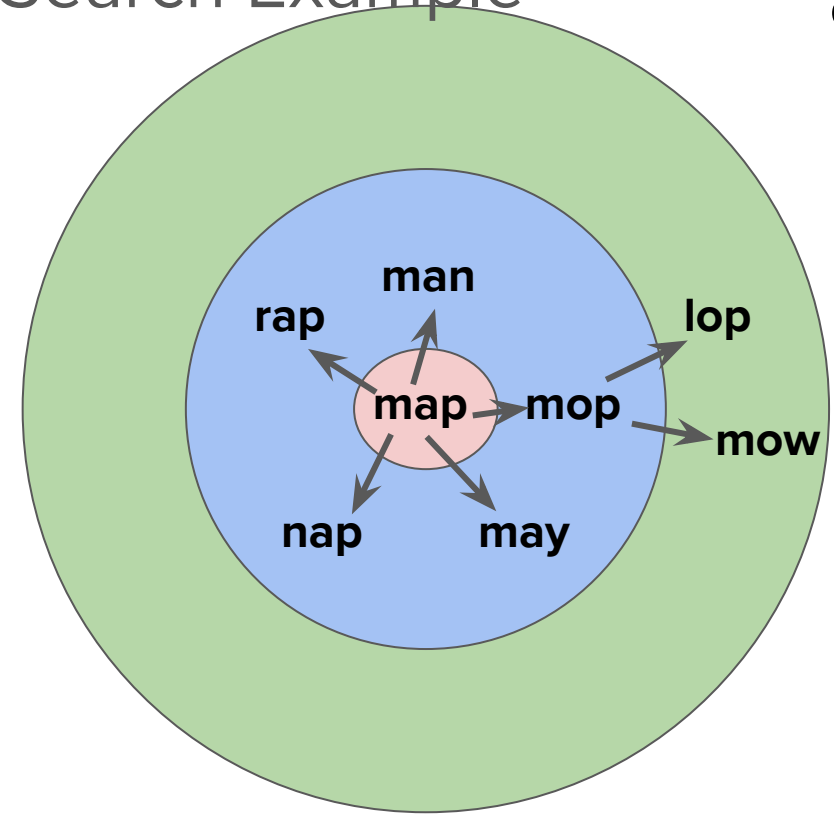

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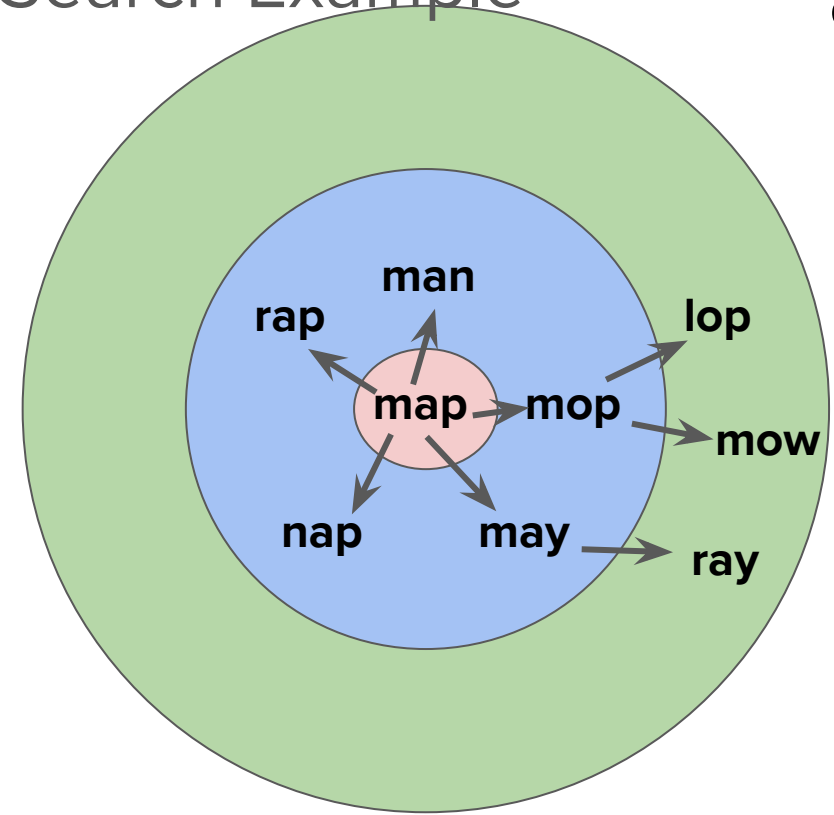

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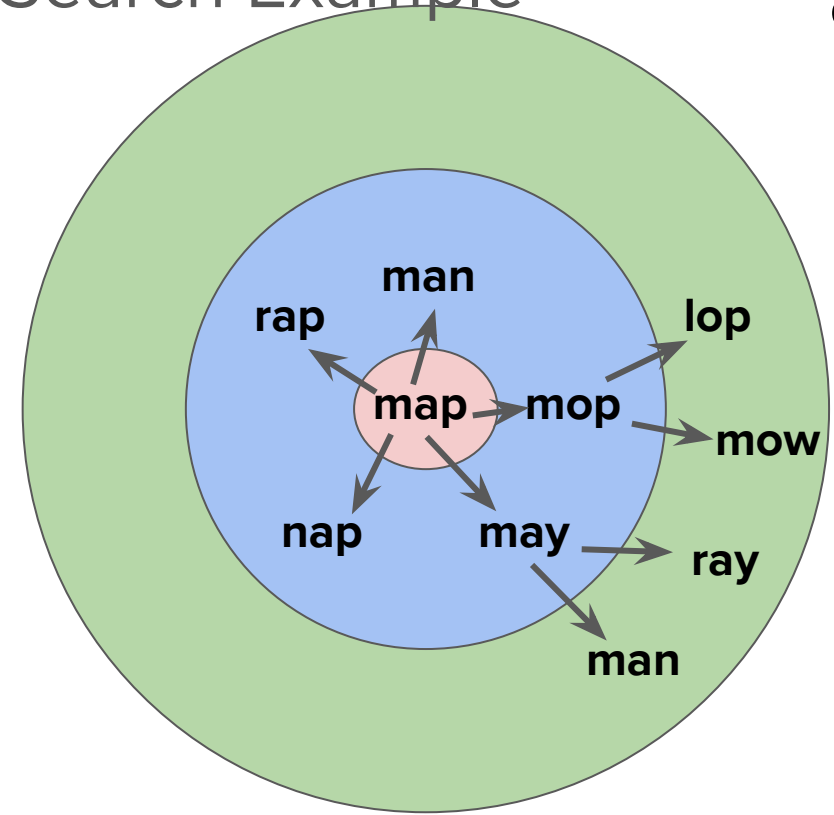

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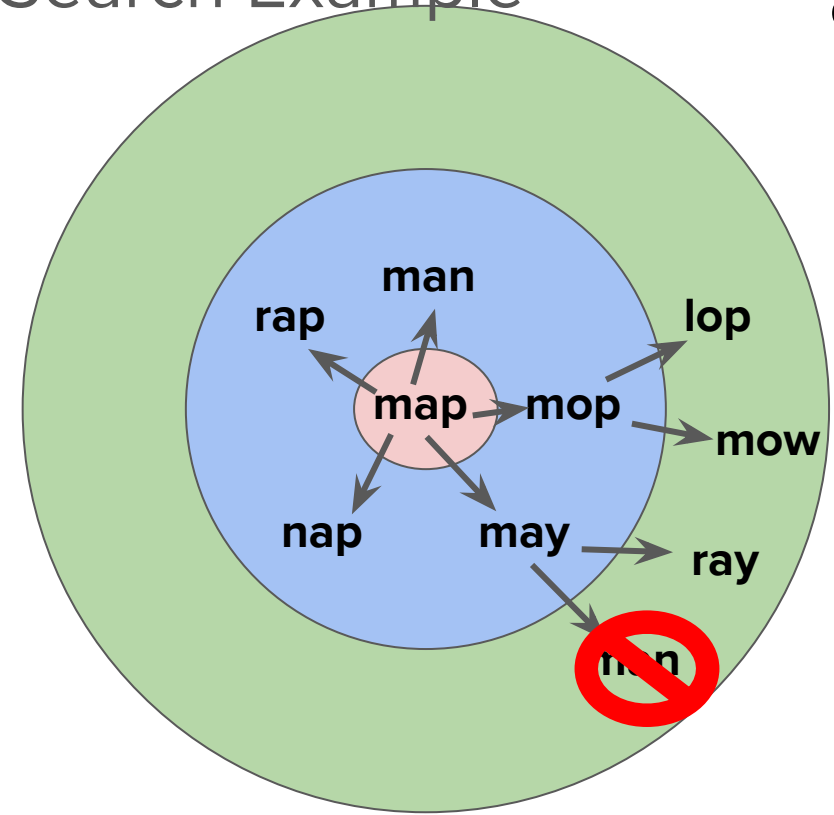

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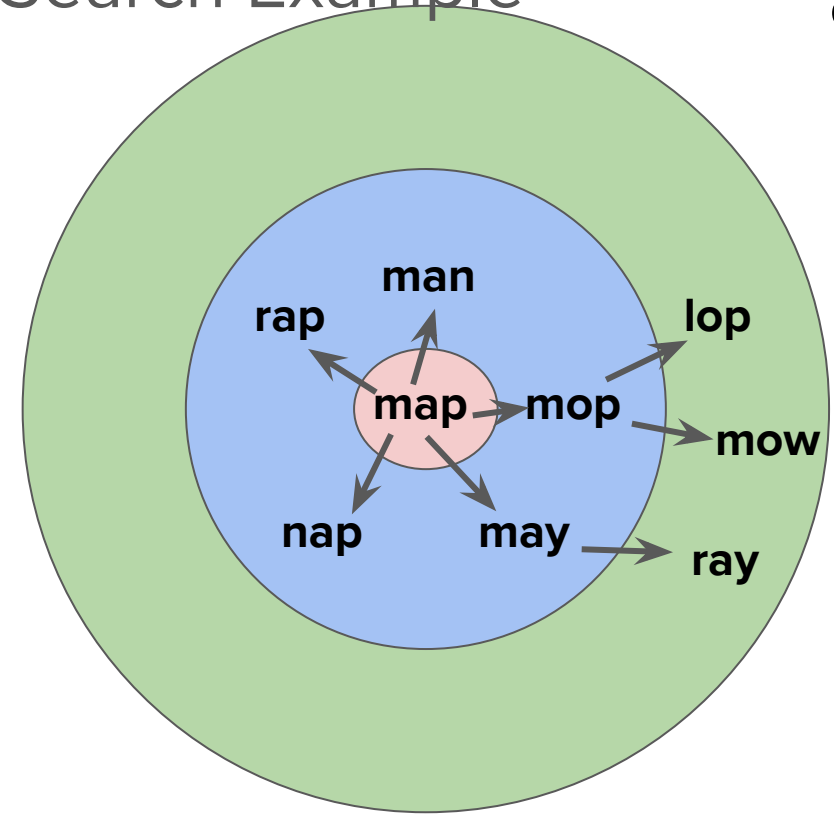

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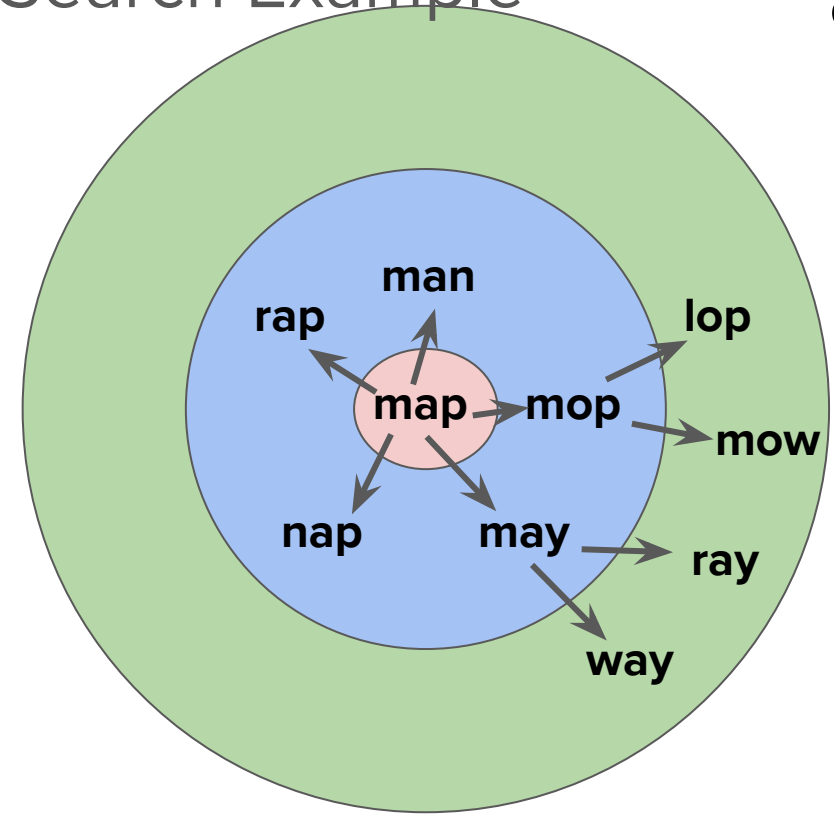

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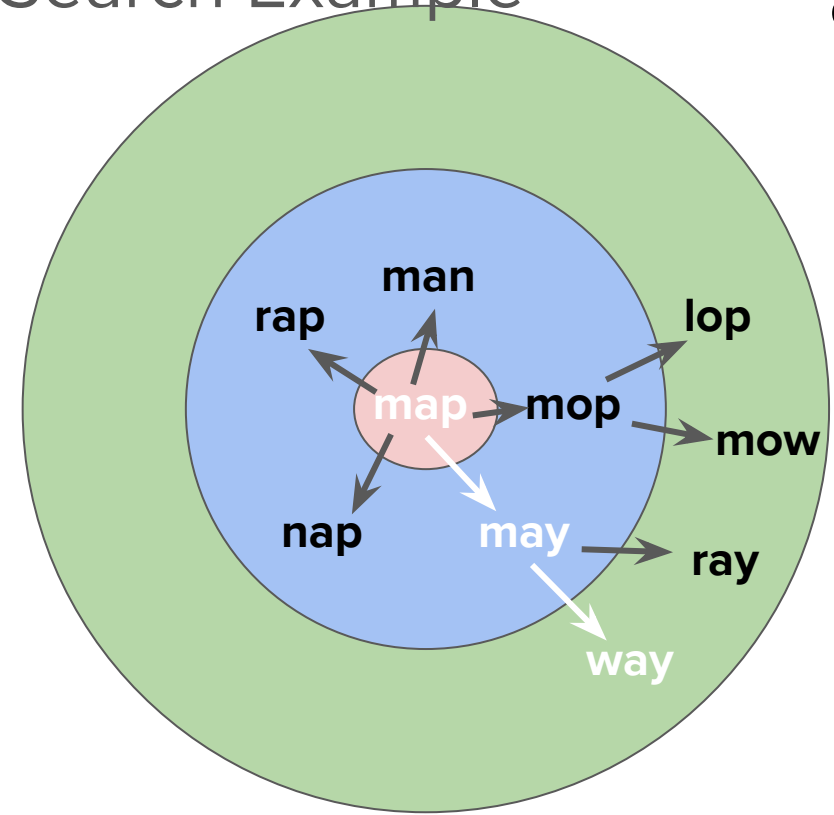

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1 step away
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Success! We have found a valid word ladder
map -> may -> way

Formalizing BFS

Breadth-First Search Data Structures

We need...

- A data structure to represent (partial word) ladders
  - Desired characteristics: We should be able to easily access the most recent word added to the word ladder

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What data structures should we use for each of these components?

Breadth-First Search Data Structures

We need...

- A data structure to represent (partial word) ladders
  - `Stack<string>`
- A data structure to store all the partial word ladders that we have generated so far and have yet to explore
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  - `Stack<string>`
- A data structure to store all the partial word ladders that we have generated so far and have yet to explore
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- A data structure to keep track of all the words that we've explored so far, so that we avoid getting stuck in loops
  - `Set<string>`

Breadth-First Search Pseudocode

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Create an empty queue and an empty set of visited locations
Create an initial word ladder containing the starting word and add it to the queue
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Breadth-First Search Pseudocode

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Create an empty queue and an empty set of visited locations
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While the queue is not empty
    Remove the next partial ladder from the queue
    Set the current search word to be the word at the top of the ladder
    If the current word is the destination, then return the current ladder
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        If the neighbor hasn't yet been visited
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    If the current word is the destination, then return the current ladder
    Generate all "neighboring" words that are valid English words and one letter away from the current word
    Loop over all neighbor words
        If the neighbor hasn't yet been visited
            Create a copy of the current ladder
            Add the neighbor to the top of the new ladder and mark it visited
            Add the new ladder to the back of the queue of partial ladders
```

Live Coding:
Implementing BFS

[Qt Creator]

Live Coding: Implementing BFS

[Qt Creator]

We hope that you find this to be a helpful resource when working on Assignment 2. However, we do not encourage trying to copy the code as a starting point. The problems are distinctly different, and you will benefit from explicitly developing your own problem-specific pseudocode first.