Artificial Intelligence

Search Agents

Goal-based agents

- **Reflex agents**: use a mapping from states to actions.
- **Goal-based agents**: problem solving agents or planning agents.

Goal-based agents

- Agents that work towards a **goal**.
- Agents consider the impact of **actions** on future **states**.
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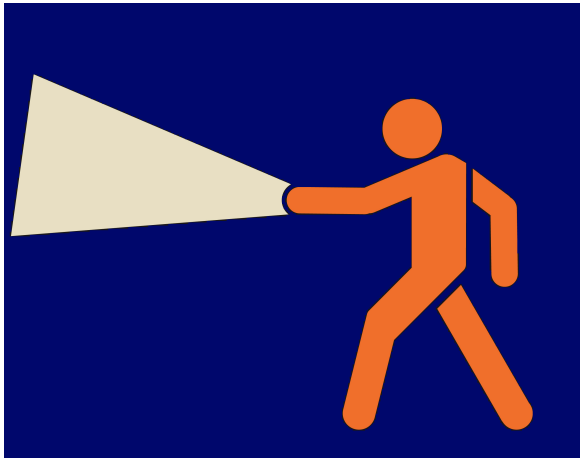
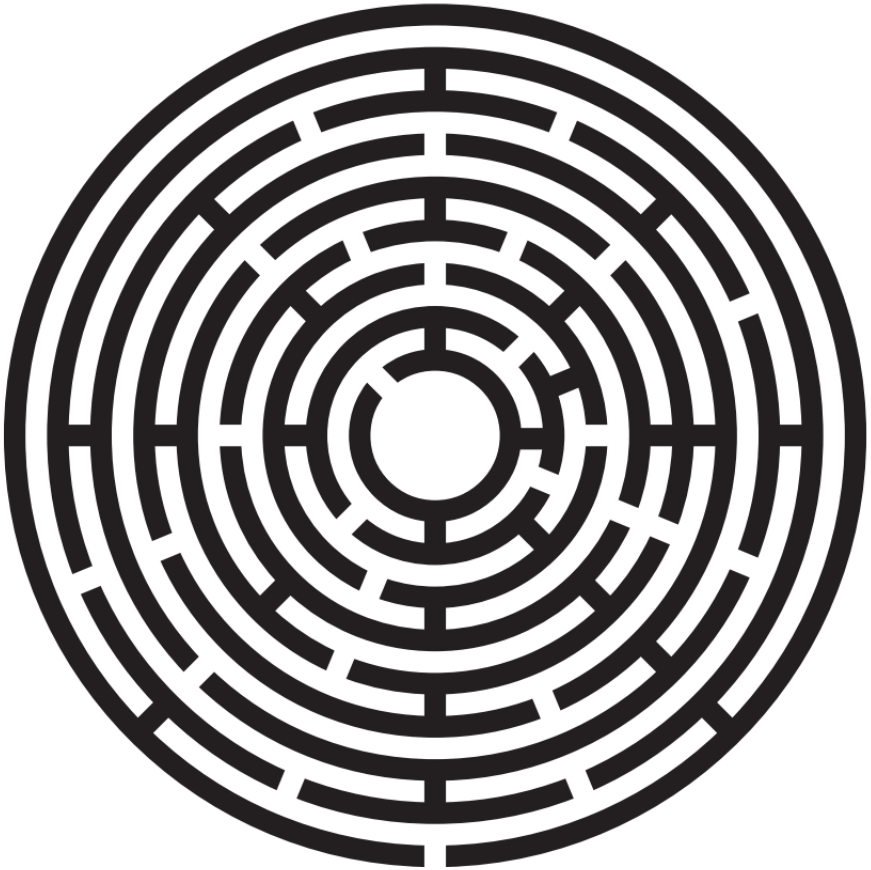
- Formalized as a **search** through possible **solutions**.



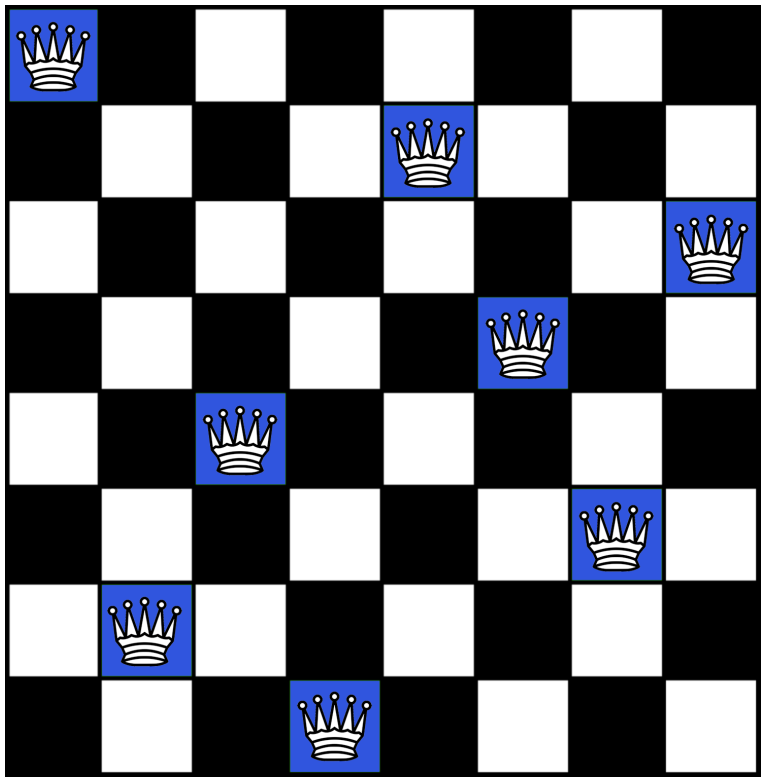
Examples



Examples

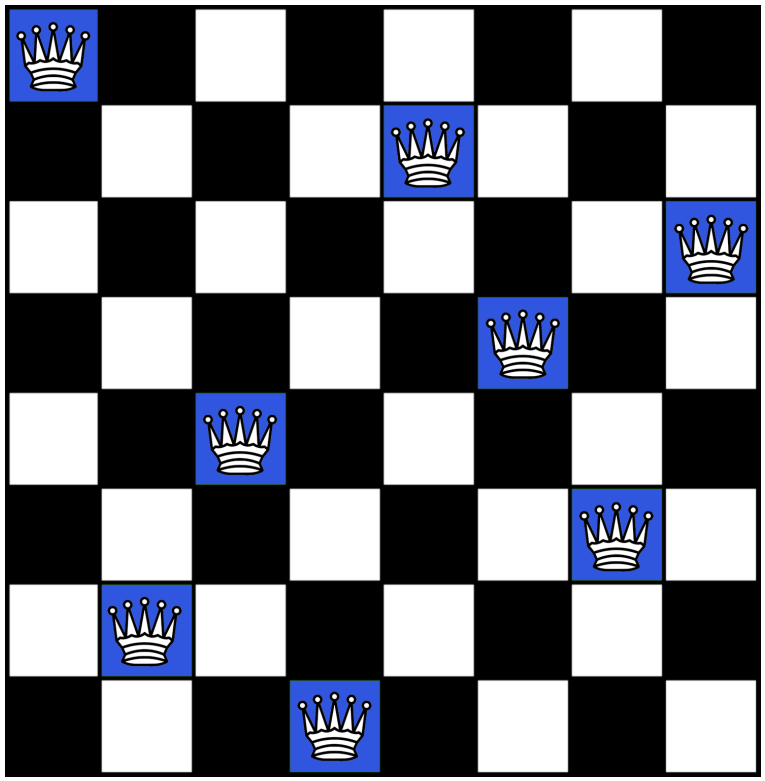
EXPLORE!

Examples



The 8-queen problem: on a chess board, place 8 queens so that no queen is attacking any other horizontally, vertically or diagonally.

Examples



Number of possible sequences to investigate:

$$64 * 63 * 62 * ... * 57 = 1.8 \times 10^{14}$$

Problem solving as search

1. **Define the problem through:**
   (a) Goal formulation
   (b) Problem formulation
2. **Solving the problem as a 2-stage process:**
   (a) Search: "mental" or "offline" exploration of several possibilities
   (b) Execute the solution found

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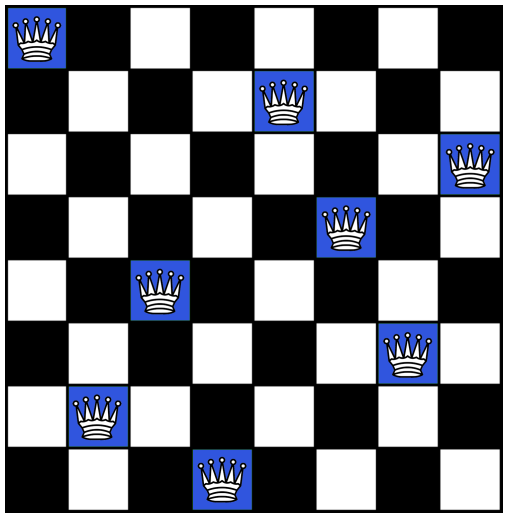
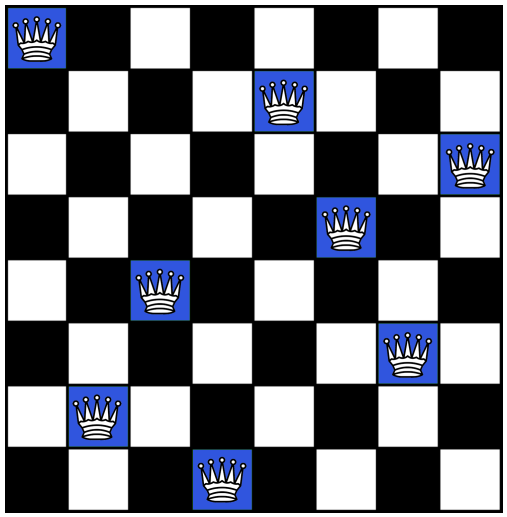
- **Path cost:** function that assigns a numeric cost to a path w.r.t. performance measure

Examples



- **States:** all arrangements of 0 to 8 queens on the board.

Examples



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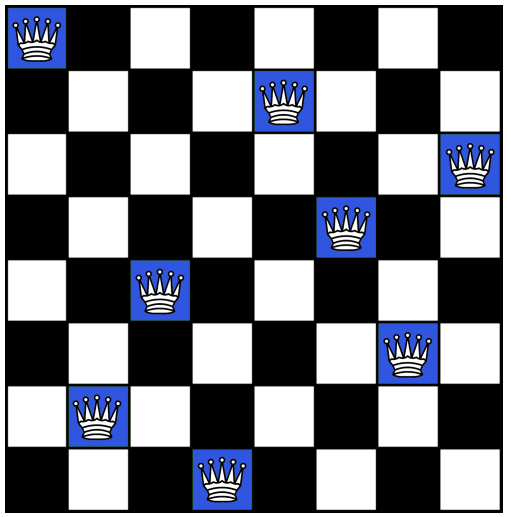

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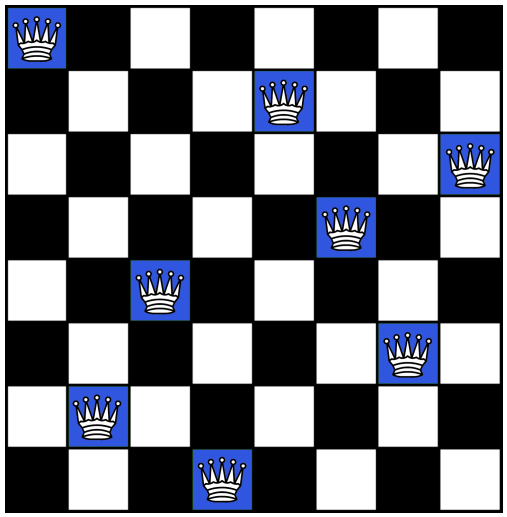

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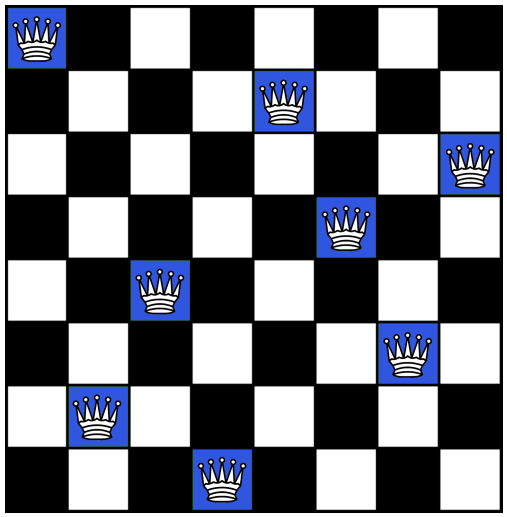
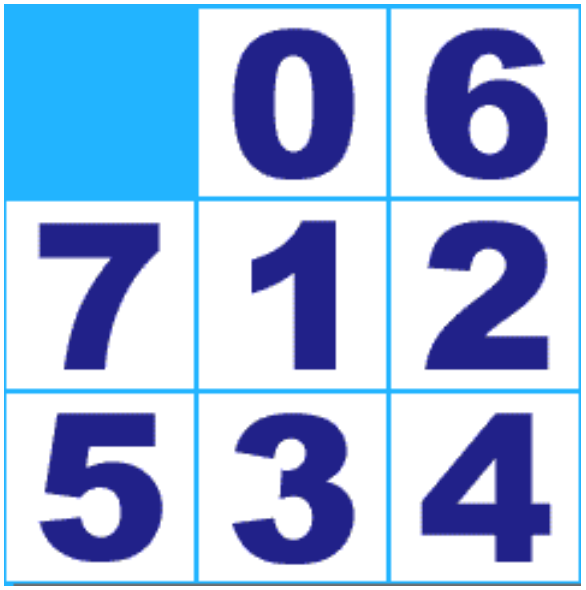


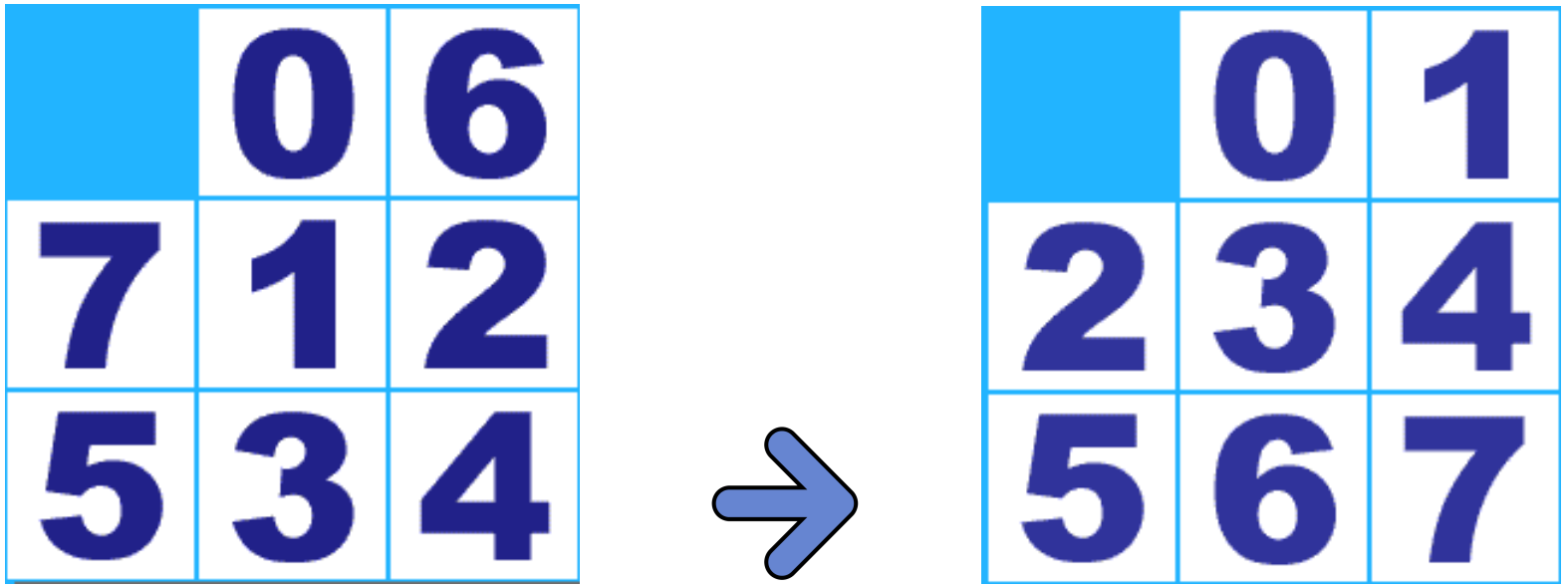
- **States:** all arrangements of 0 to 8 queens on the board.
- **Initial state:** No queen on the board
- **Actions:** Add a queen to any empty square
- **Transition model:** updated board
- **Goal test:** 8 queens on the board with none attacked

Examples



8 puzzles

Examples



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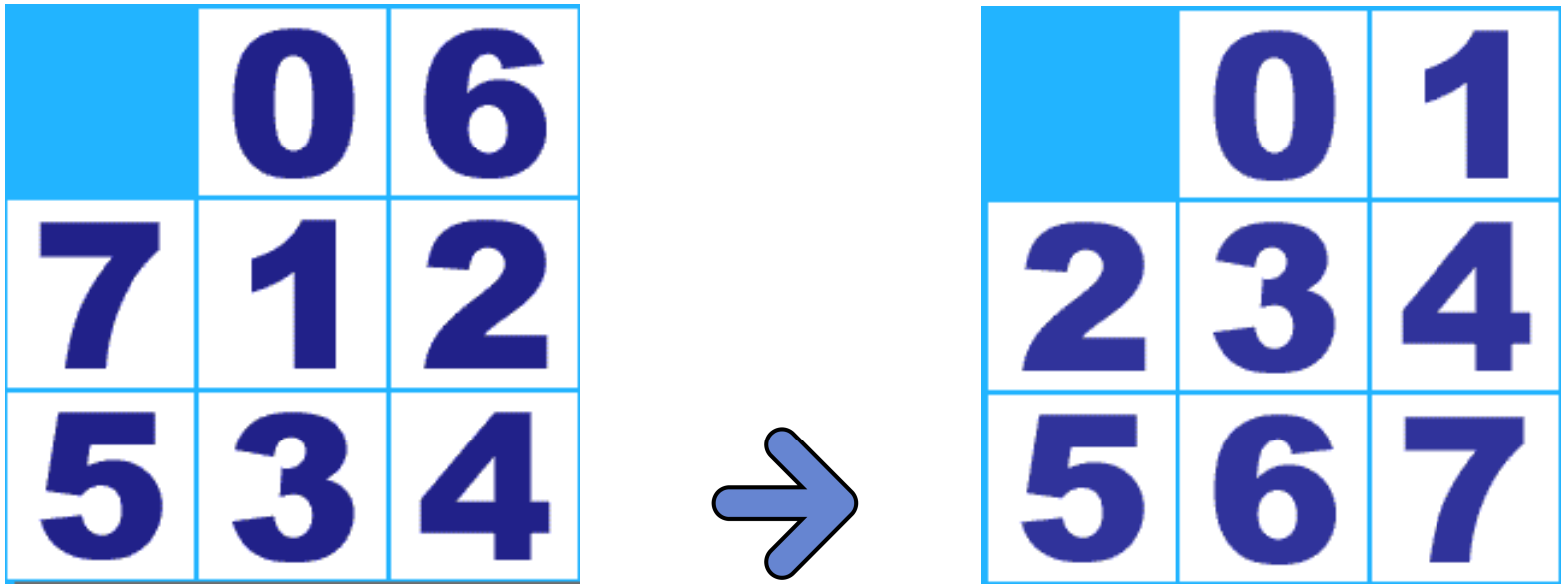
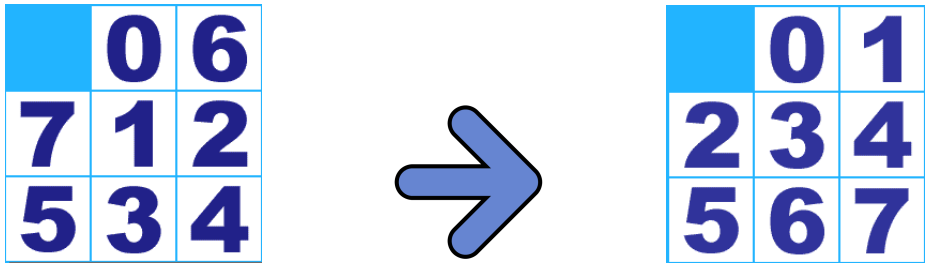


Start State

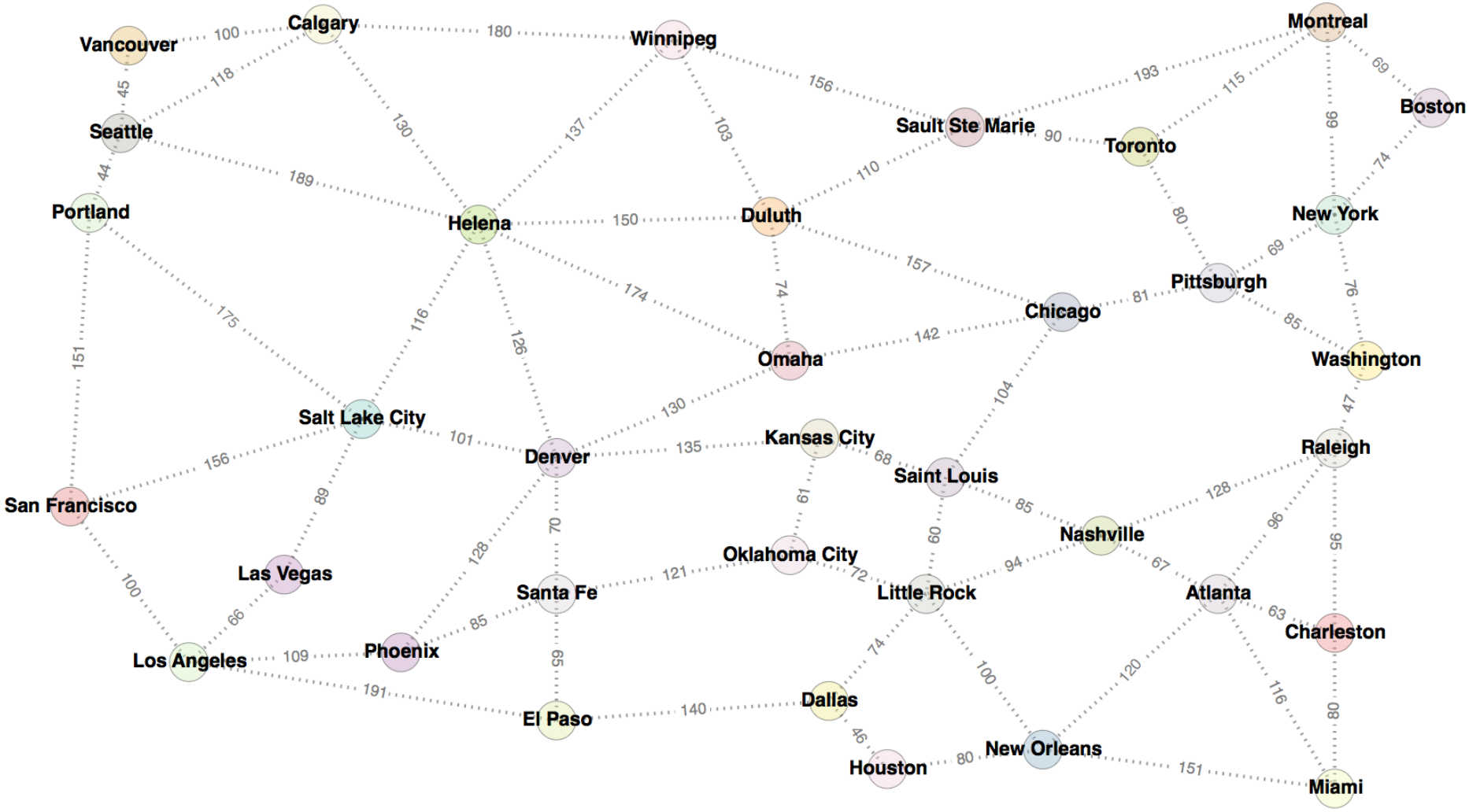
Goal State

Examples



- **States:** Location of each of the 8 tiles in the 3x3 grid
- **Initial state:** Any state
- **Actions:** Move Left, Right, Up or Down
- **Transition model:** Given a state and an action, returns resulting state
- **Goal test:** state matches the goal state?
- **Path cost:** total moves, each move costs 1.

Examples of search agents



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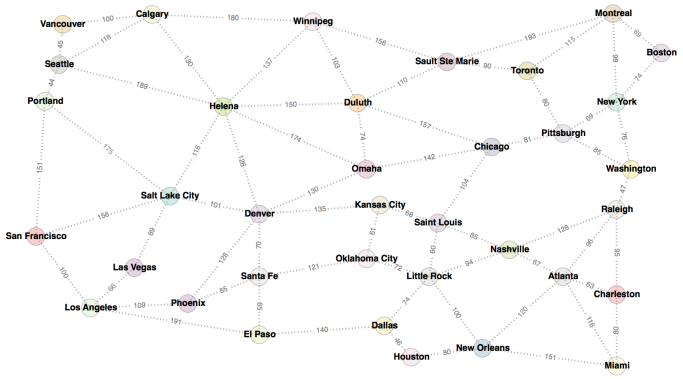


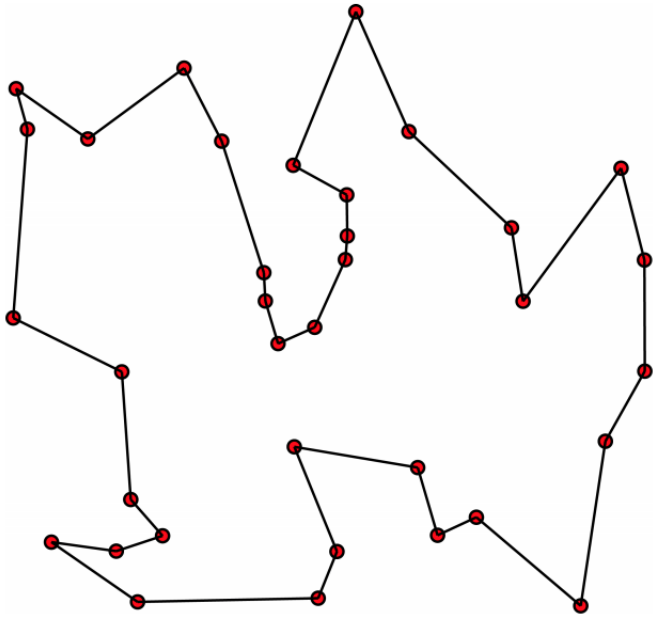
- **States:** In City where
  City $\in$ {Los Angeles, San Francisco, Denver,...}
- **Initial state:** In Boston
- **Actions:** Go New York, etc.
- **Transition model:**
  Results (In (Boston), Go (New York)) = In(New York)
- **Goal test:** In(Denver)
- **Path cost:** path length in kilometers

Real-world examples

- **Route finding problem:** typically our example of map search, where we need to go from location to location using links or transitions. Example of applications include tools for driving directions in websites, in-car systems, etc.

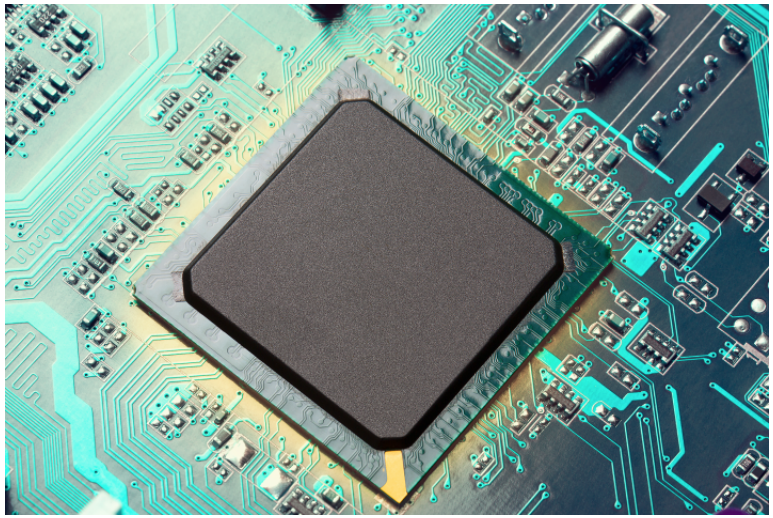
Real-world examples

- **Traveling salesperson problem:** Find the shortest tour to visit each city exactly once.



Real-world examples

- **VLSI layout:** position million of components and connections on a chip to minimize area, shorten delays. Aim: put circuit components on a chip so as they don't overlap and leave space to wiring which is a complex problem.

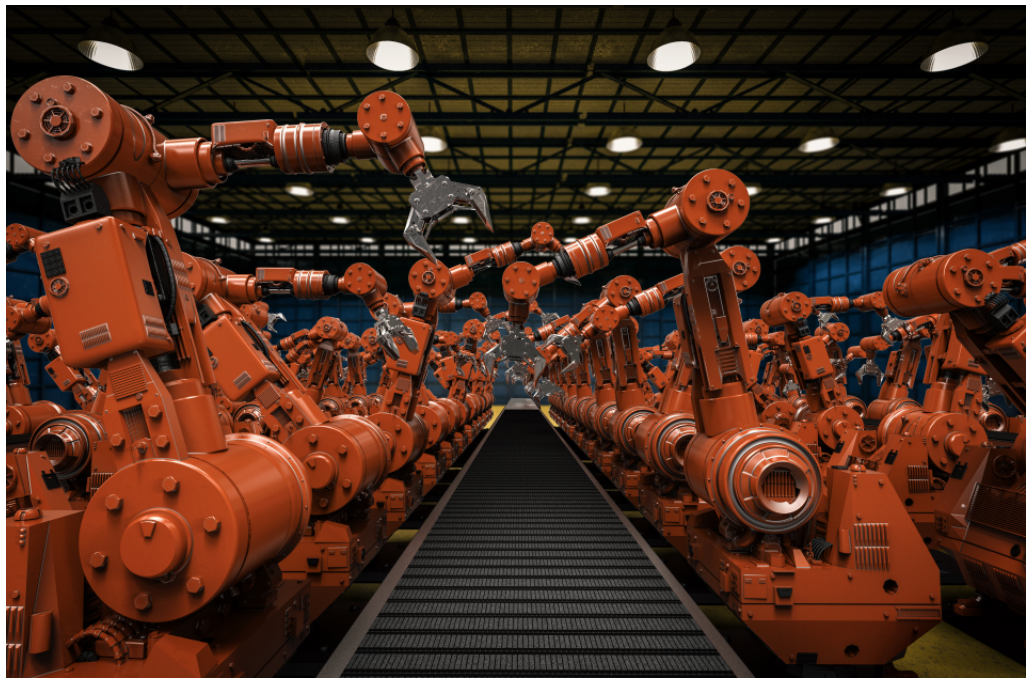


Real-world examples

- **Robot navigation:** Special case of route finding for robots with no specific routes or connections. The robot navigates in 2D or 3D space or ore where the state space and action space are potentially infinite.

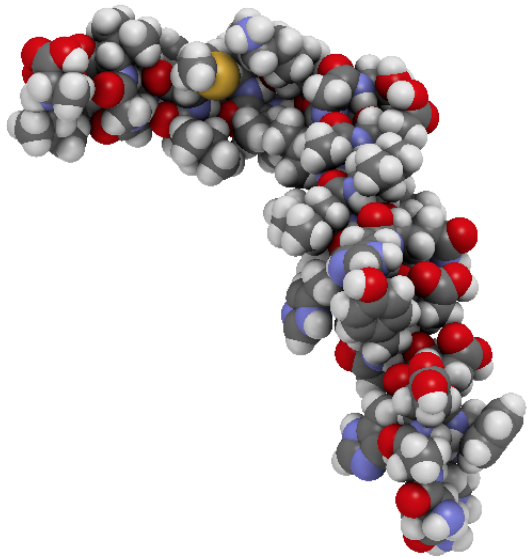
Real-world examples

- **Automatic assembly sequencing:** find an order in which to assemble parts of an object which is in general a difficult and expensive geometric search.



Real-world examples

- **Protein design:** find a sequence of amino acids that will fold into a 3D protein with the right properties to cure some disease.



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- **Search tree:** **models the sequence of actions**
  - Root: initial state
  - Branches: actions
  - Nodes: results from actions. A node has: parent, children, depth, path cost, associated state in the state space.

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- **Expand:** A function that given a node, creates all children nodes

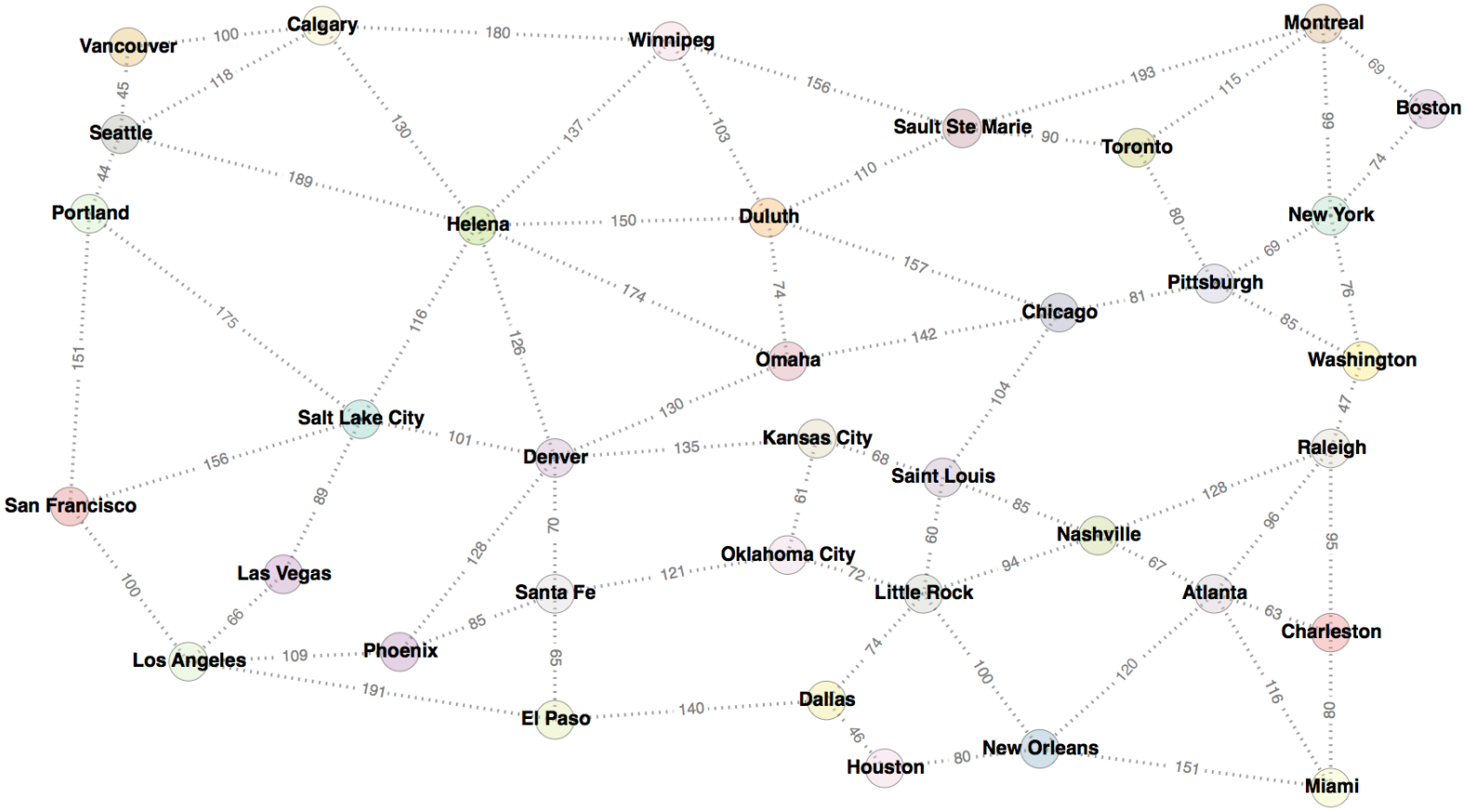
Search Space Regions

- The search space is divided into three regions:
  1. **Explored** (a.k.a. Closed List, Visited Set)
  2. **Frontier** (a.k.a. Open List, the Fringe)
  3. **Unexplored**.
- The essence of search is moving nodes from regions (3) to (2) to (1), and the essence of search strategy is deciding the order of such moves.
- In the following we adopt the following color coding: orange nodes are explored, grey nodes are the frontier, white nodes are unexplored, and black nodes are failures.

Tree search

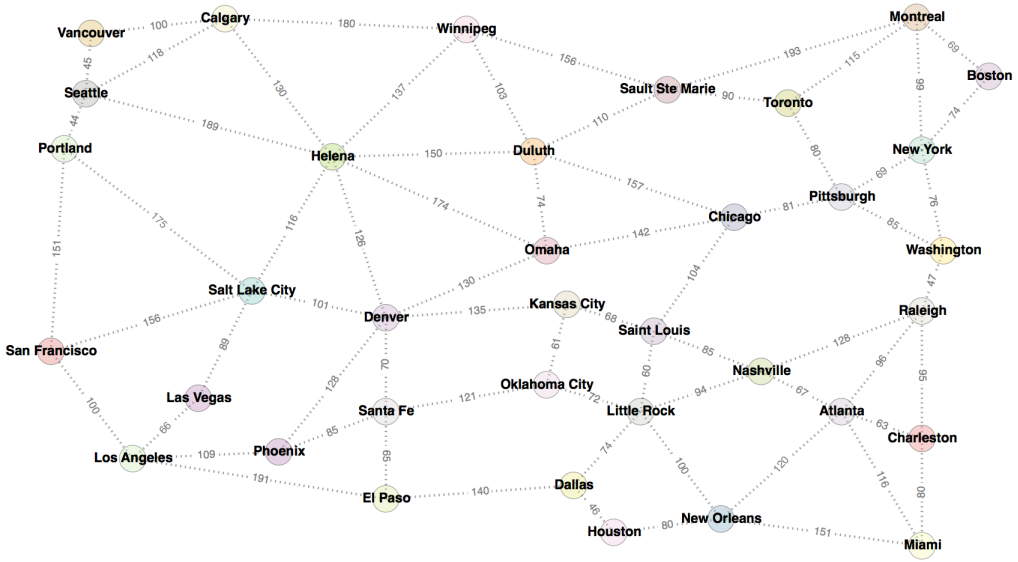
```
function TREE-SEARCH(initialState, goalTest)
    returns SUCCESS or FAILURE :

    initialize frontier with initialState

    while not frontier.isEmpty():
        state = frontier.remove()

        if goalTest(state):
            return SUCCESS(state)

        for neighbor in state.neighbors():
            frontier.add(neighbor)

    return FAILURE
```

Examples of search agents



Let's show the first steps in growing the search tree to find a route from San Francisco to another city

Examples of search agents



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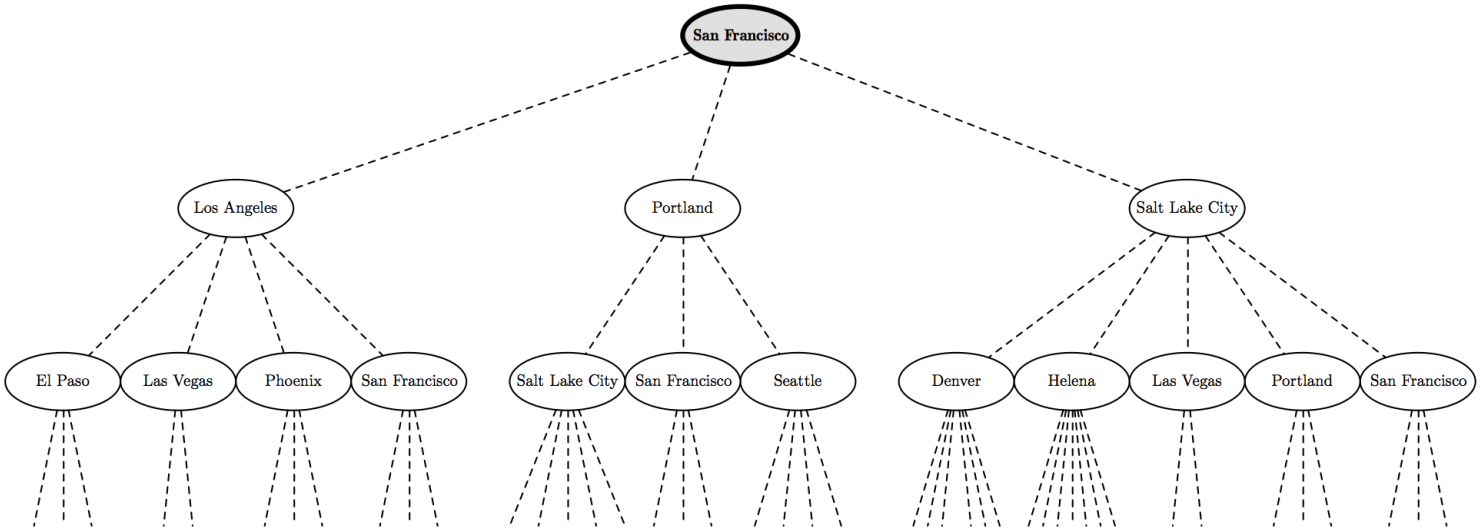

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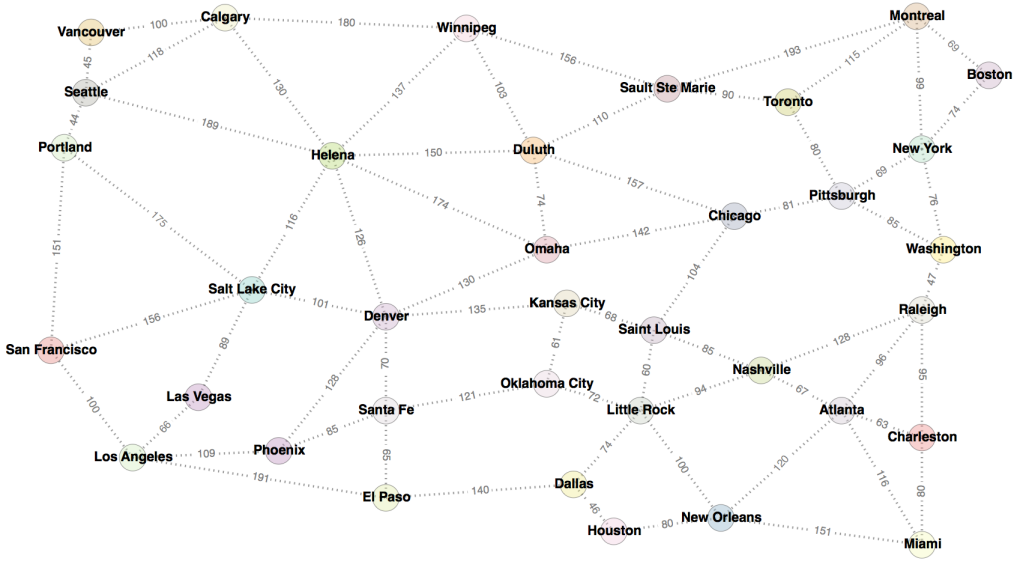

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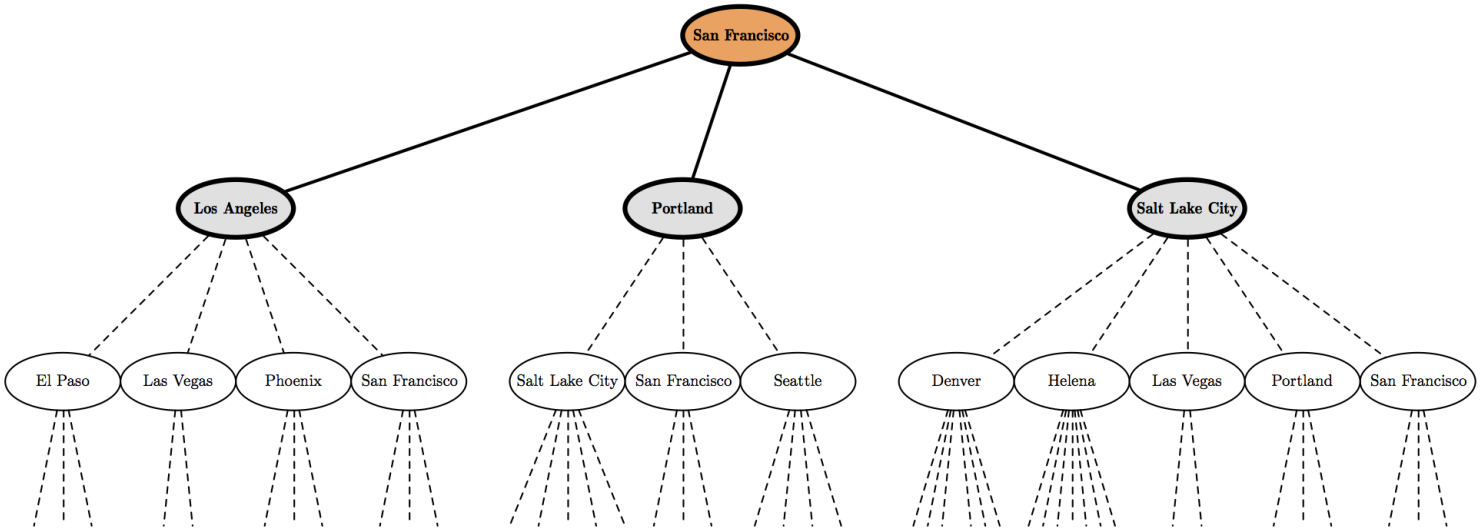

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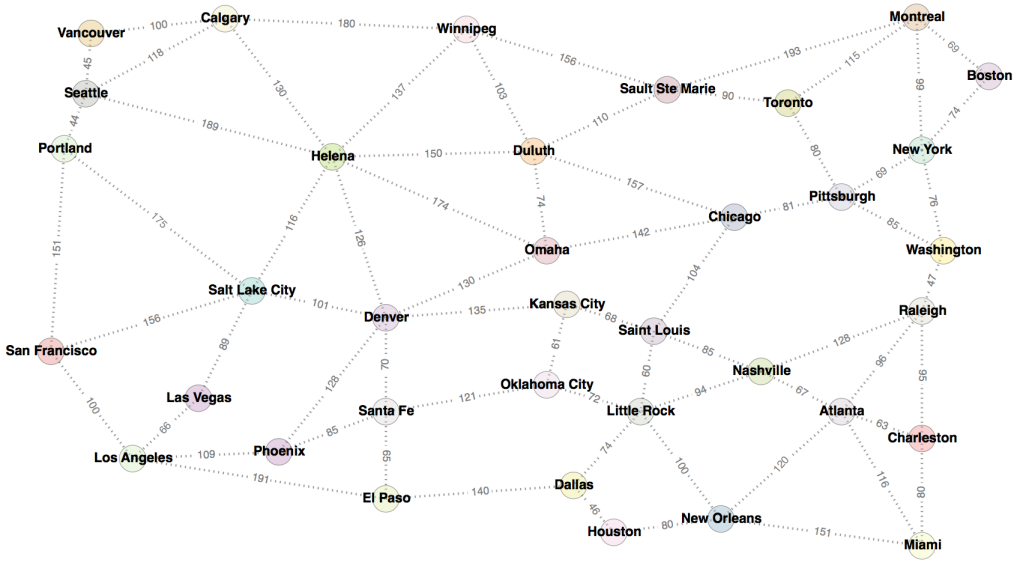


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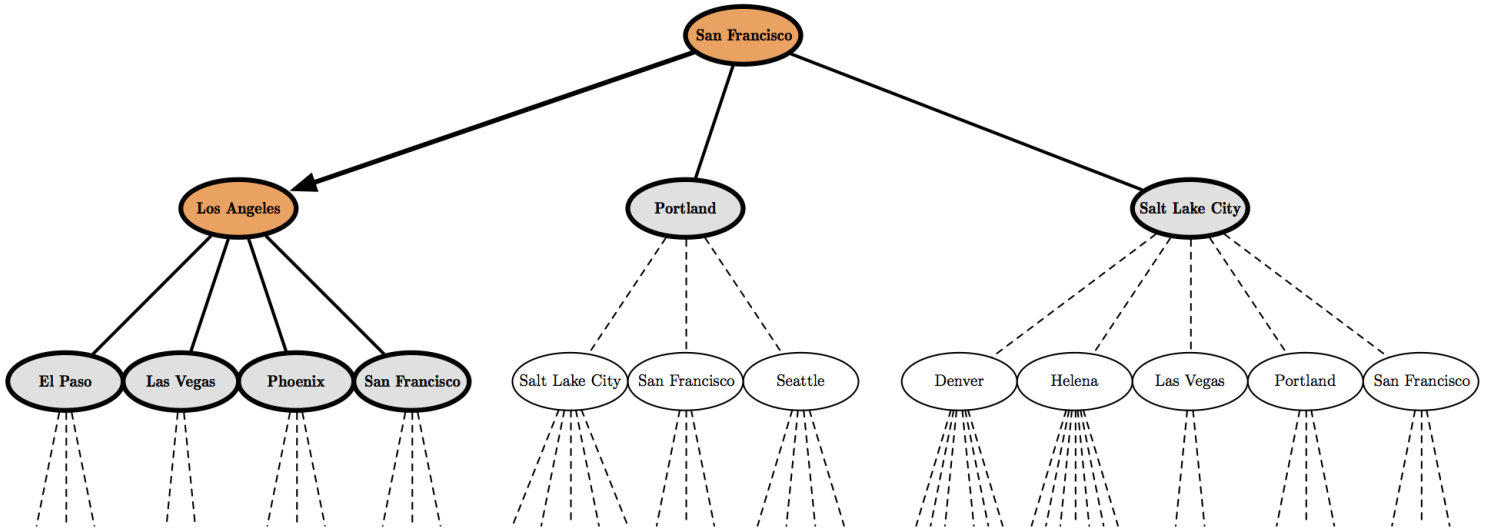

Graph search

How to handle repeated states?

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```
function GRAPH-SEARCH(initialState, goalTest)
    returns SUCCESS or FAILURE :

    initialize frontier with initialState
    explored = Set.new()

    while not frontier.isEmpty():
        state = frontier.remove()
        explored.add(state)

        if goalTest(state):
            return SUCCESS(state)

        for neighbor in state.neighbors():
            if neighbor not in frontier ∪ explored:
                frontier.add(neighbor)

    return FAILURE
```

Search strategies

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- Strategies are evaluated along the following dimensions:
  - **Completeness**
    Does it always find a solution if one exists?
  - **Time complexity**
    Number of nodes generated/expanded
  - **Space complexity**
    Maximum number of nodes in memory
  - **Optimality**
    Does it always find a least-cost solution?

Search strategies

- Time and space complexity are measured in terms of:
  - b: maximum branching factor of the search tree (actions per state).
  - d: depth of the solution
  - m: maximum depth of the state space (may be ∞) (also noted sometimes D).
- Two kinds of search: Uninformed and Informed.

Credit

- Artificial Intelligence, A Modern Approach. Stuart Russell and Peter Norvig. Third Edition. Pearson Education.

  http://aima.cs.berkeley.edu/