CSE 433
Artificial Intelligence
4th year, Computer Engineering
Fall 2012, Lecture #2

Hazem Shehata

Dept. of Computer & Systems Engineering
Zagazig University

September 24th, 2012

Credits to Dr. Mohamed El Abd for the slides

Adminstrivia

Notes

- Tutorials:
  - Starting this week (Eng. Amr).

Course Info:

- Website: http://www.hshehata.name.eg/courses/cse433

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- Assignment #1:
  - Programming assignment
  - To be released next week.
  - Work in groups of two.

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Outline

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Problem solving by searching

Introduction

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Problem solving by searching

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- The process of looking for a sequence of actions to reach a goal is called search.
- A search algorithm takes a *problem* as an input and returns a *solution* in the form of an action sequence.
- Search is central in many AI systems:
  - Theorem proving, VLSI layout, Game playing, Navigation, *etc*.

Problem solving by searching

Requirements of searching

- Define the problem:
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  - Define the actions the agent can perform.
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- Define the solution:
  - The goal itself?
  - The path (i.e. sequence of actions) to get to the goal?

Problem solving by searching

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Problem solving by searching

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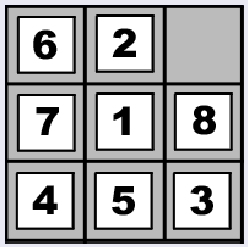
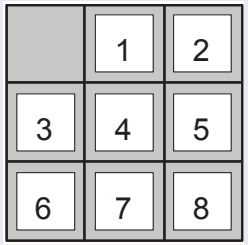
- This is known as a ***STATE-SPACE*** problem formulation.

Problem solving by searching

A puzzle example





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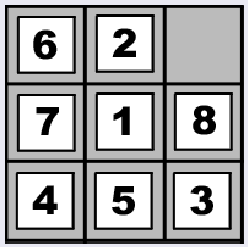

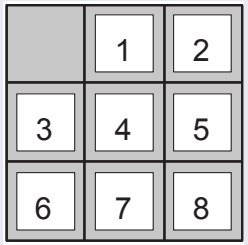

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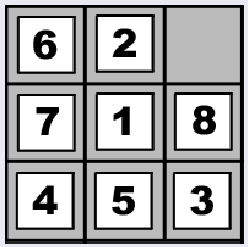

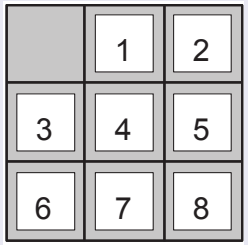

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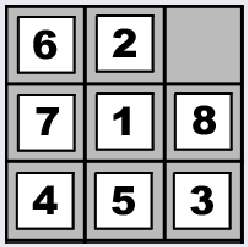

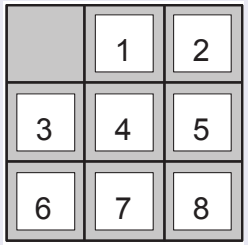

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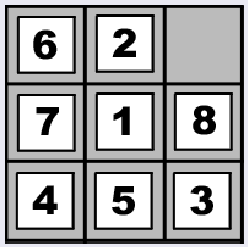

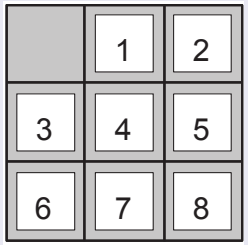

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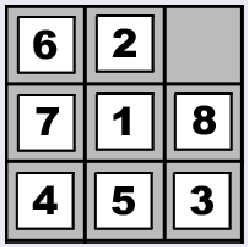

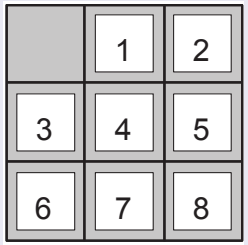

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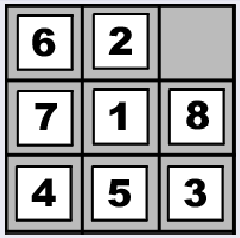

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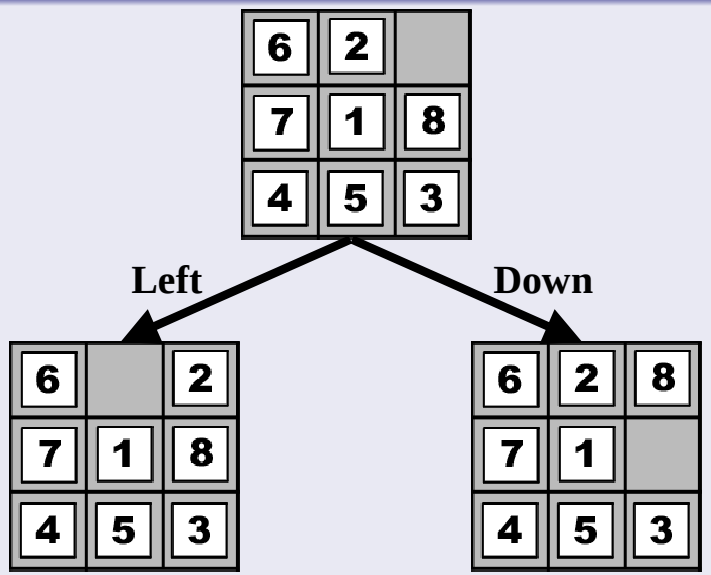

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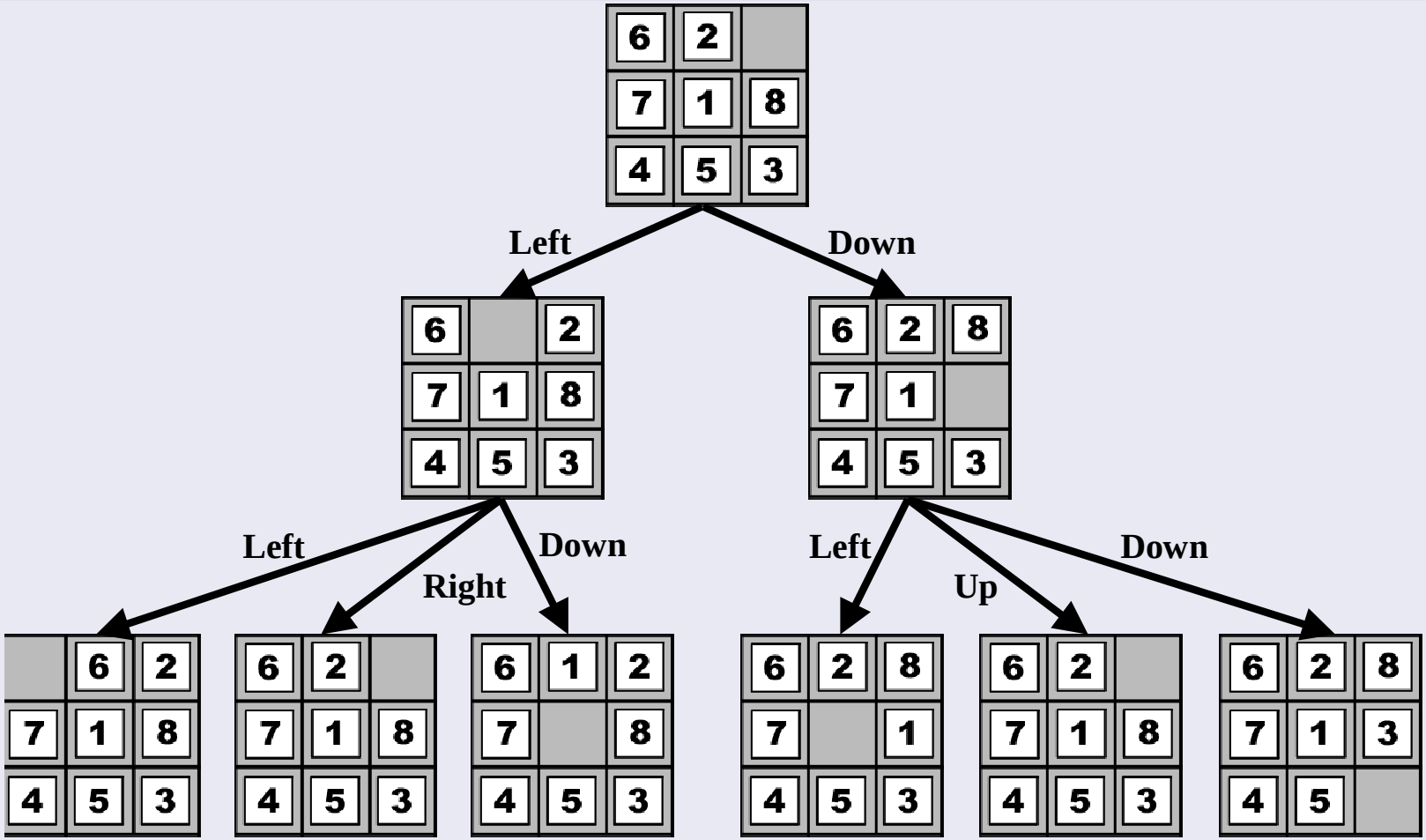

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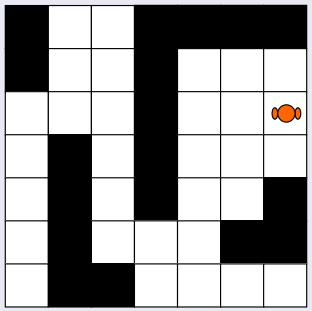

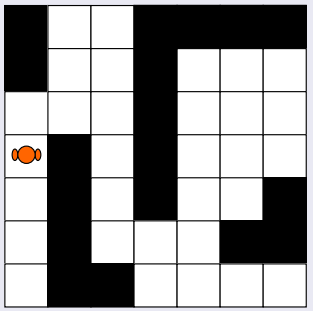

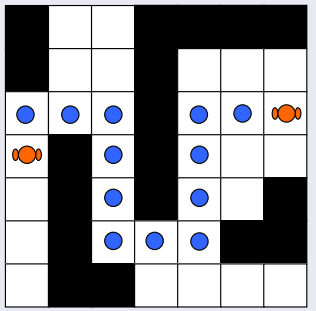

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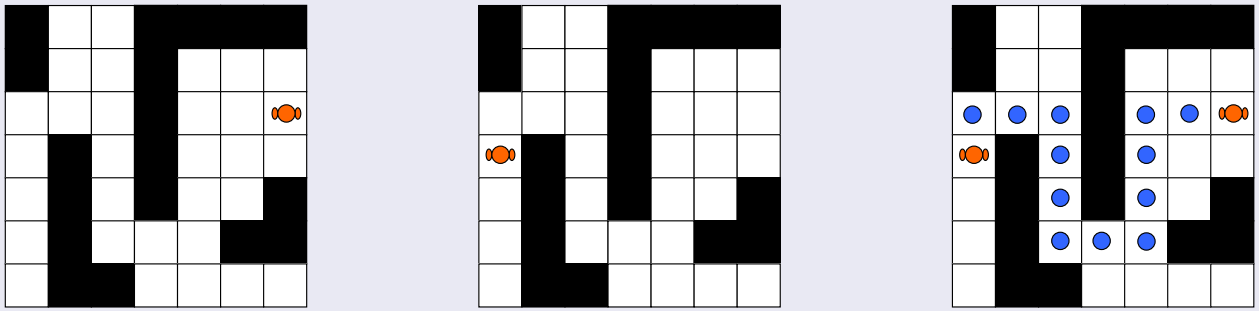

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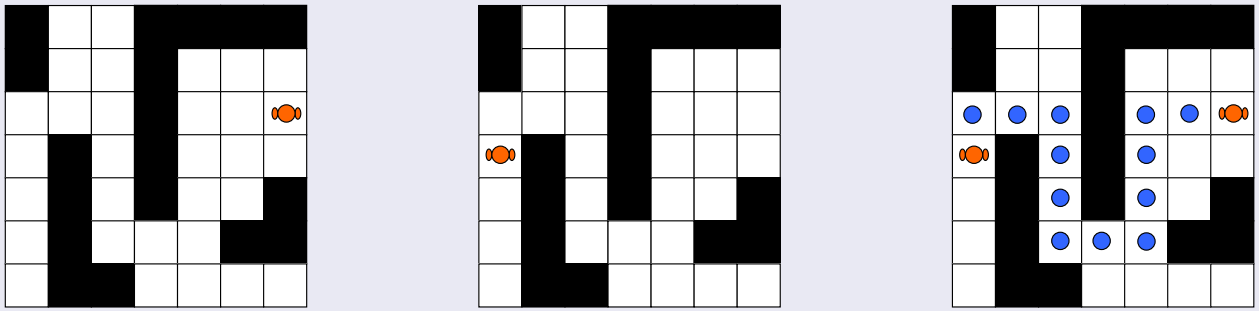

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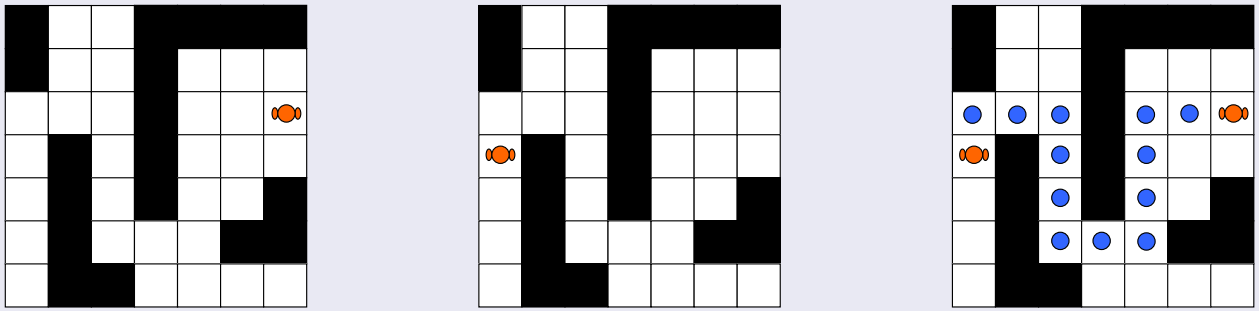

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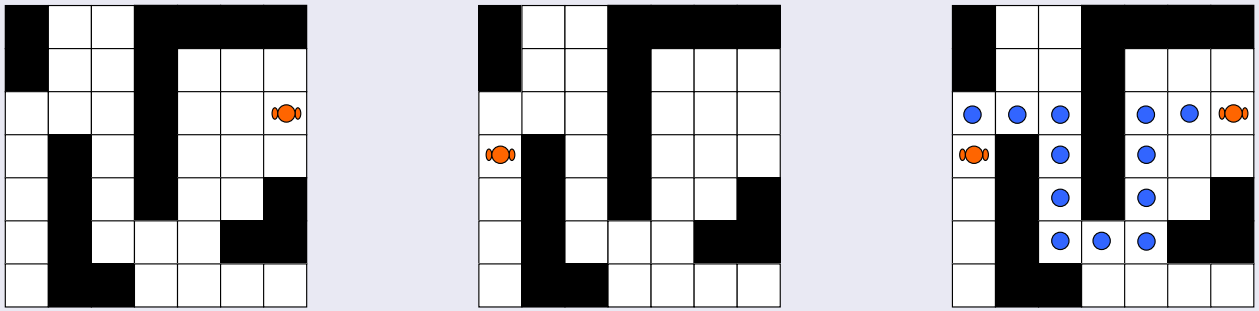

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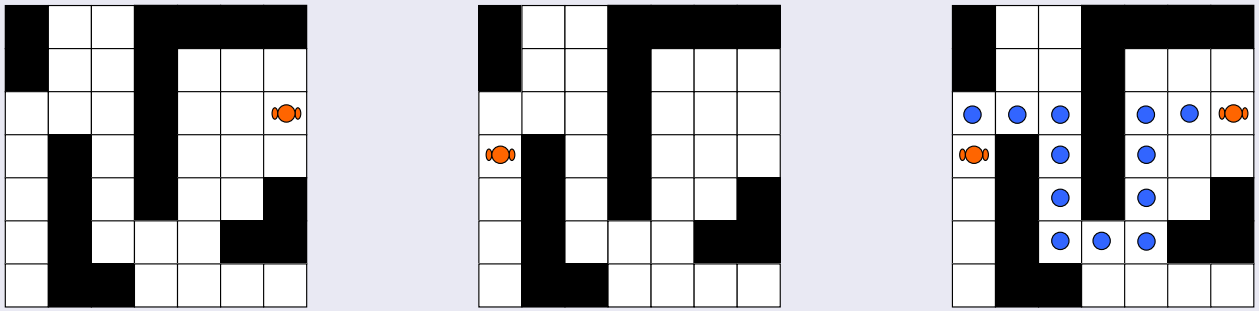

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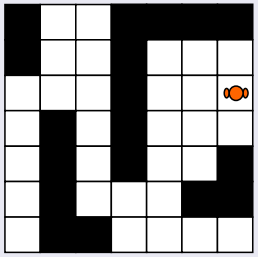

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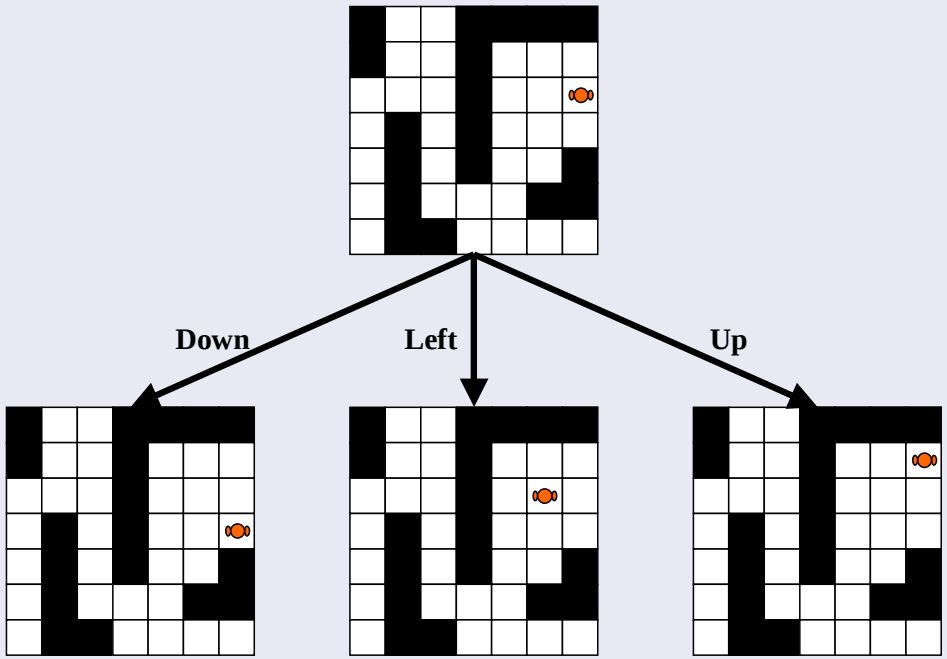

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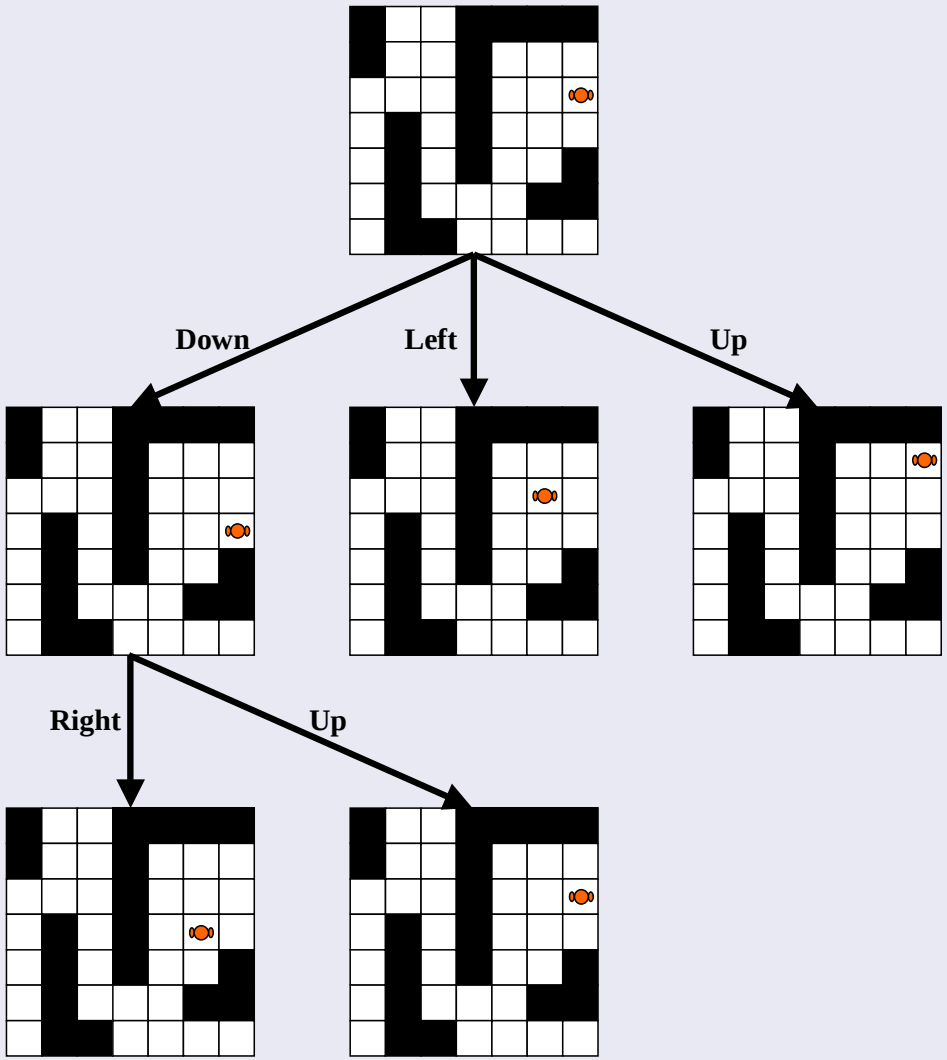

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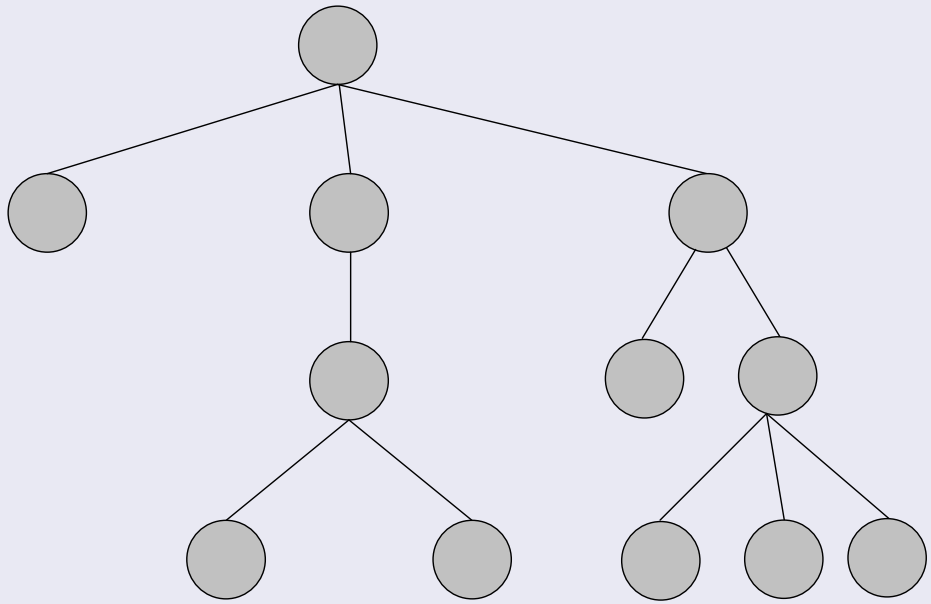

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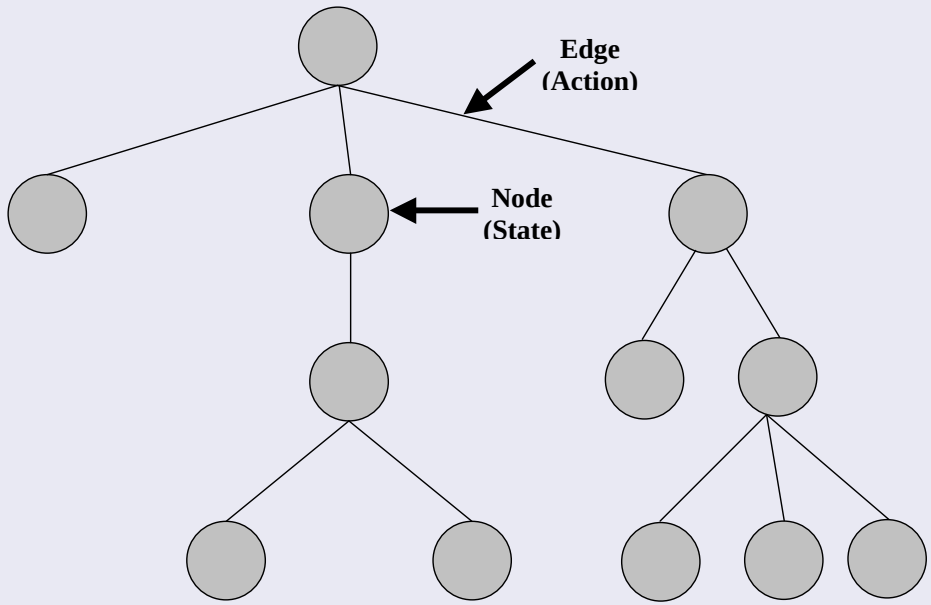

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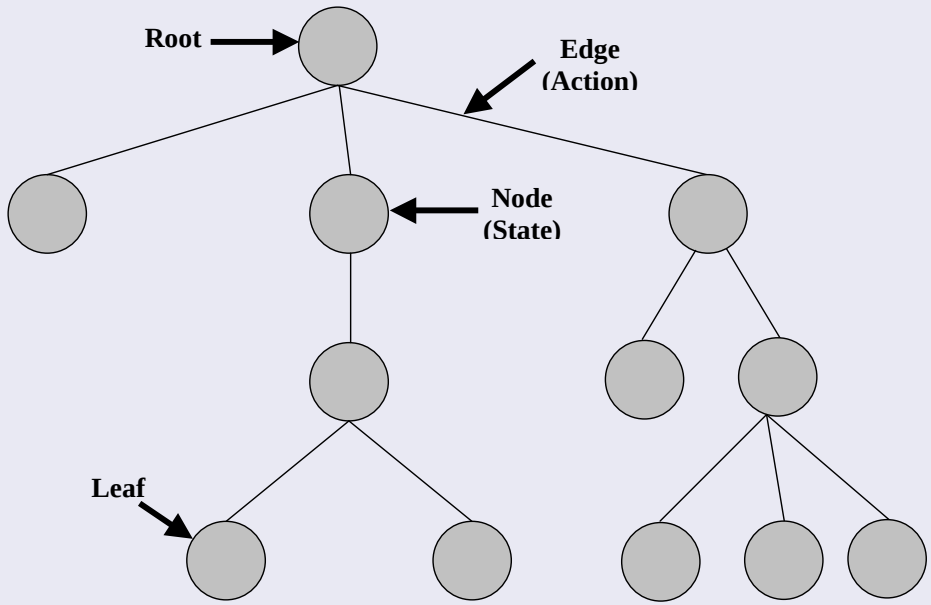

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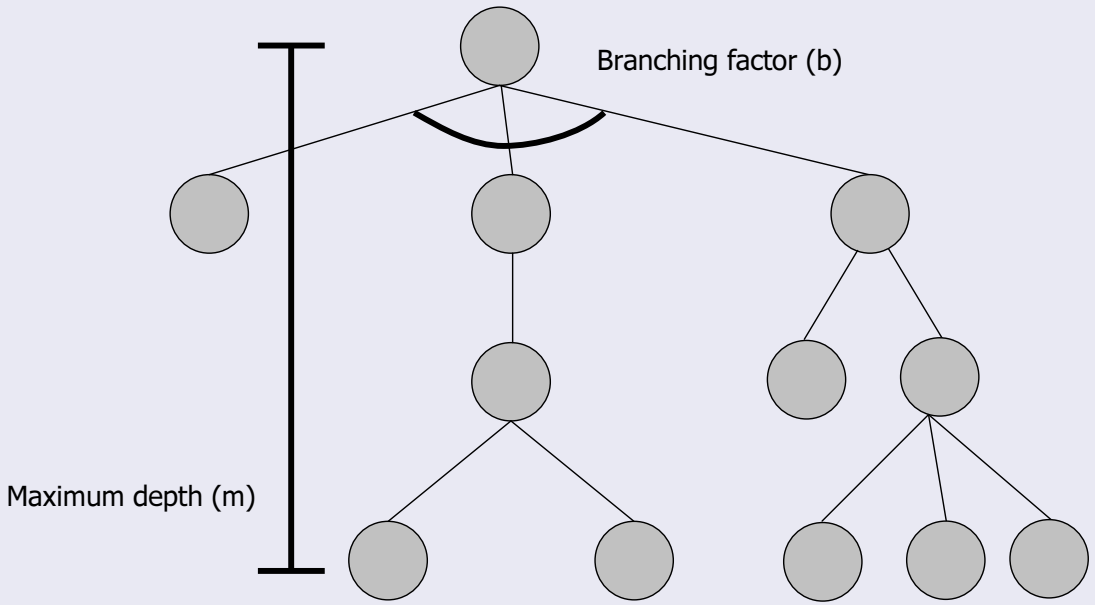

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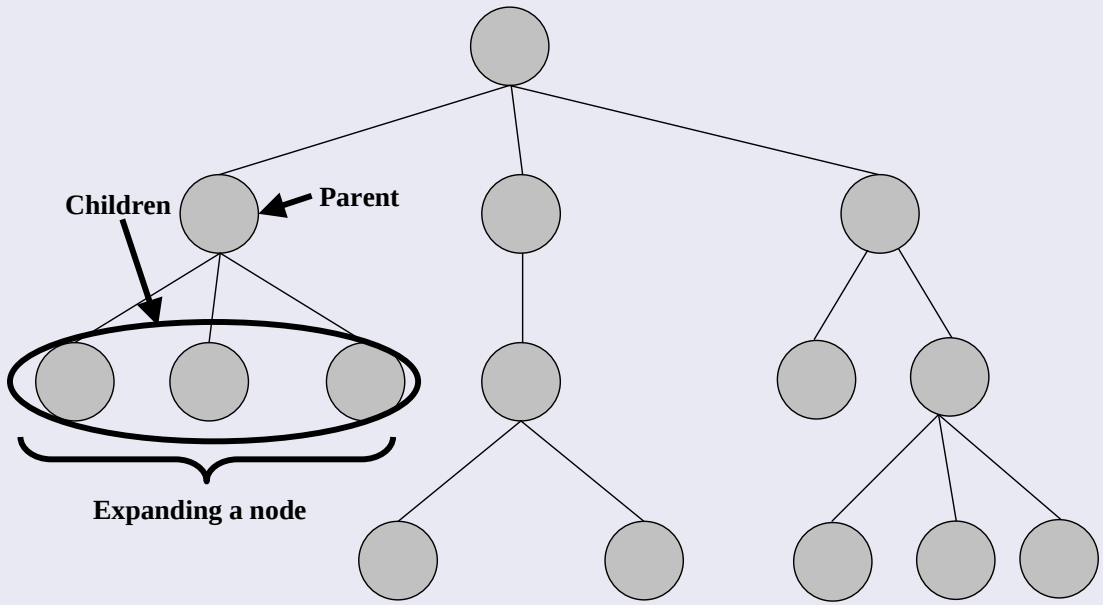

Search Algorithms

General tree-search algorithm

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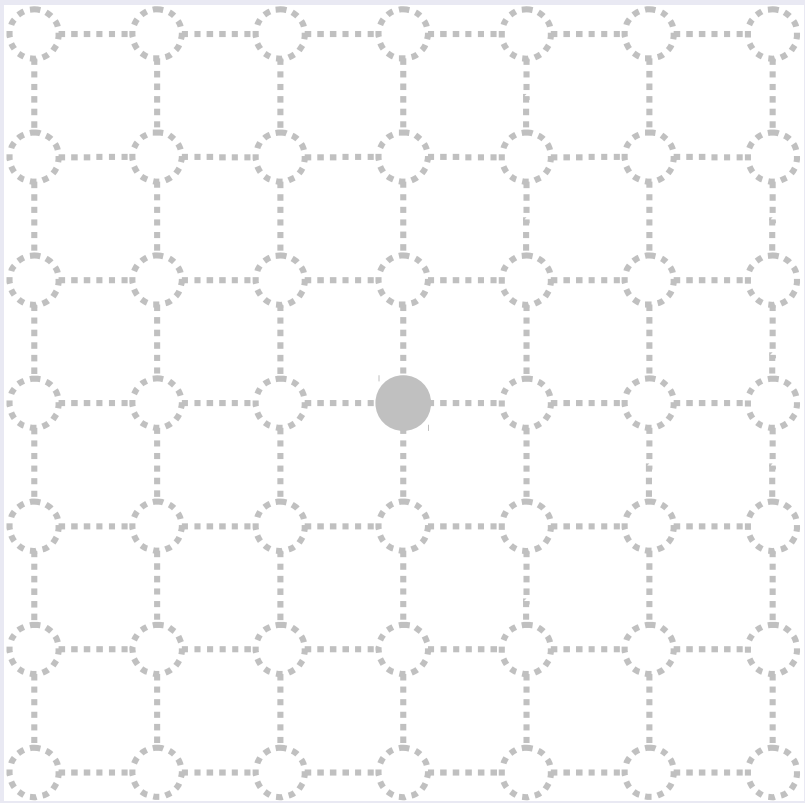
    expand the chosen node, adding the resulting node to the frontier
  end

Search Algorithms

Tree-Search on a rectangular grid problem



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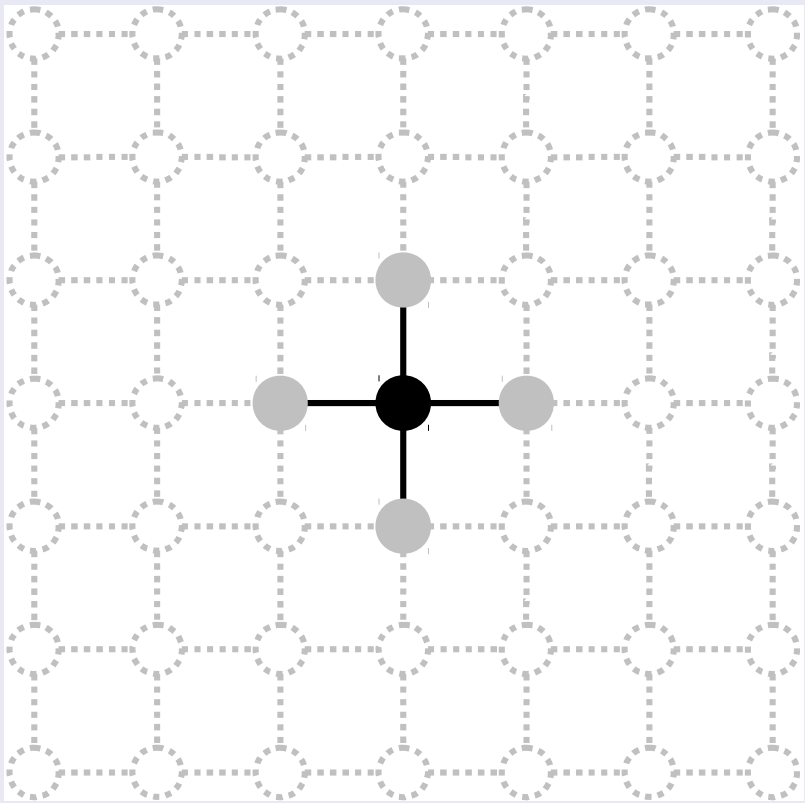

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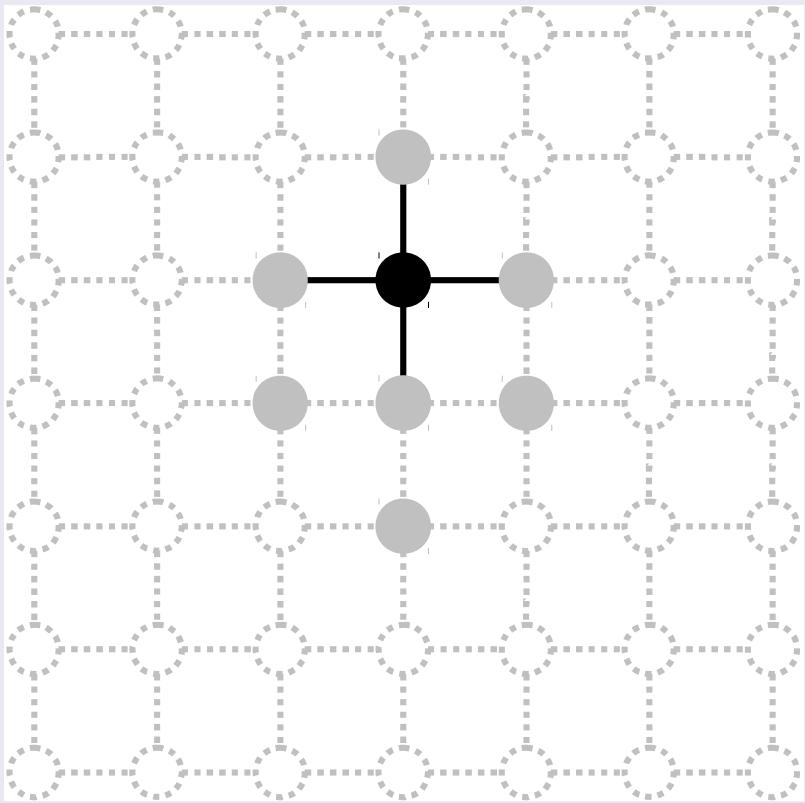

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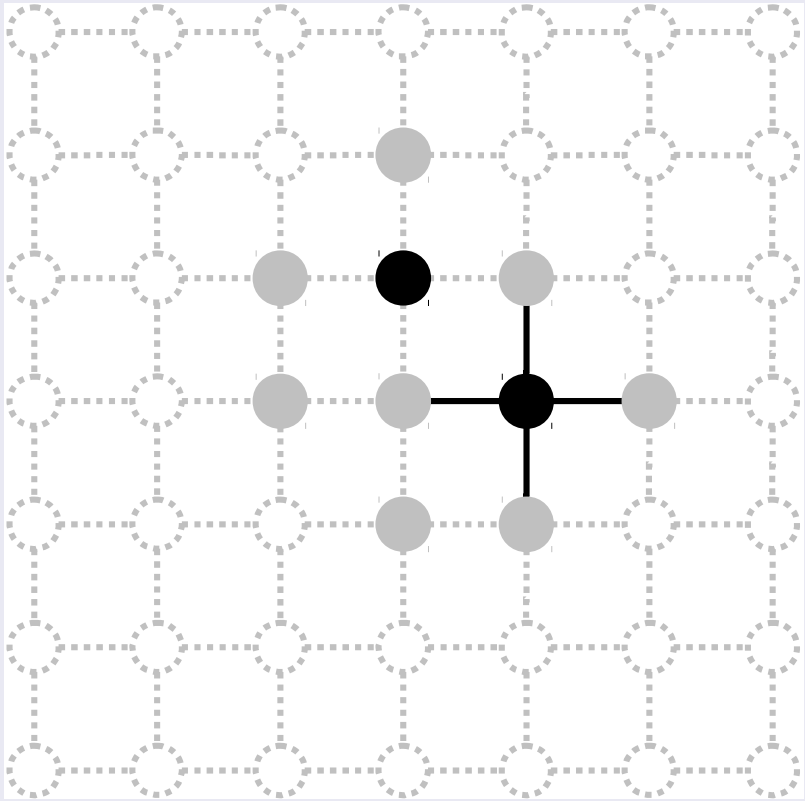

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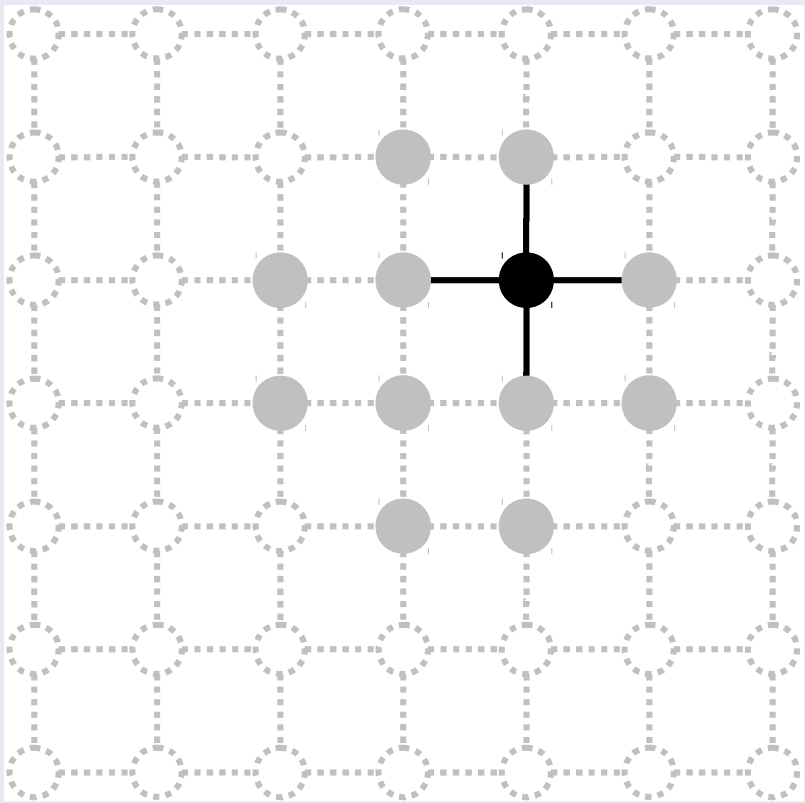
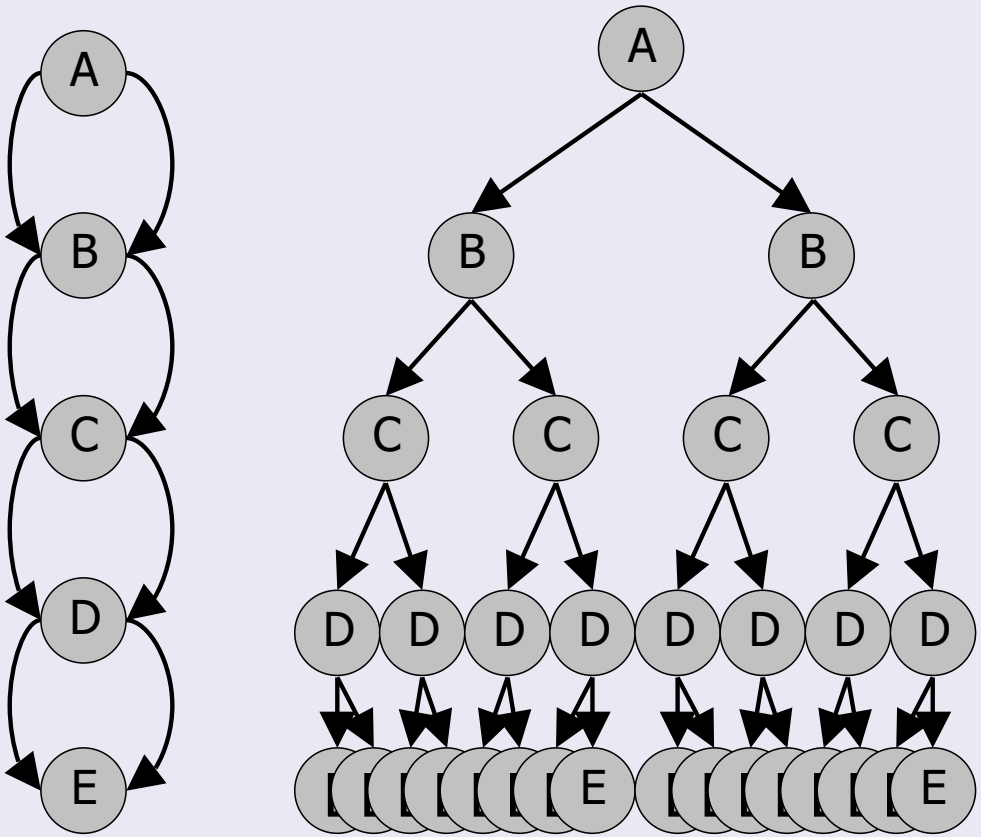


Search Algorithms

Multiple paths to the same state



Search Algorithms

Repeated states

- Unavoidable in problems where:
  - Actions are reversible (*e.g.,* , rectangular grid problems).
  - Multiple paths to the same state are possible.

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- Can be solved by augmenting the tree search algorithm with a data structure called the explored set (a.k.a., the closed list) to keep track of the explored states.
- The tree search algorithm becomes a graph search algorithm.

Search Algorithms

General graph-search algorithm

GRAPH-SEARCH(*problem*) **returns** a solution, or failure
  initialize the frontier using the initial state of a *problem*
  ...
  loop do
    if the frontier is empty **then return** failure
    choose a leaf node and remove it from the frontier
    if the node contains a goal state **then return** the corresponding solution
    ...
    expand the chosen node, adding the resulting node to the frontier
      ...
  end

Search Algorithms

General graph-search algorithm

GRAPH-SEARCH(*problem*) **returns** a solution, or failure
  initialize the frontier using the initial state of a *problem*
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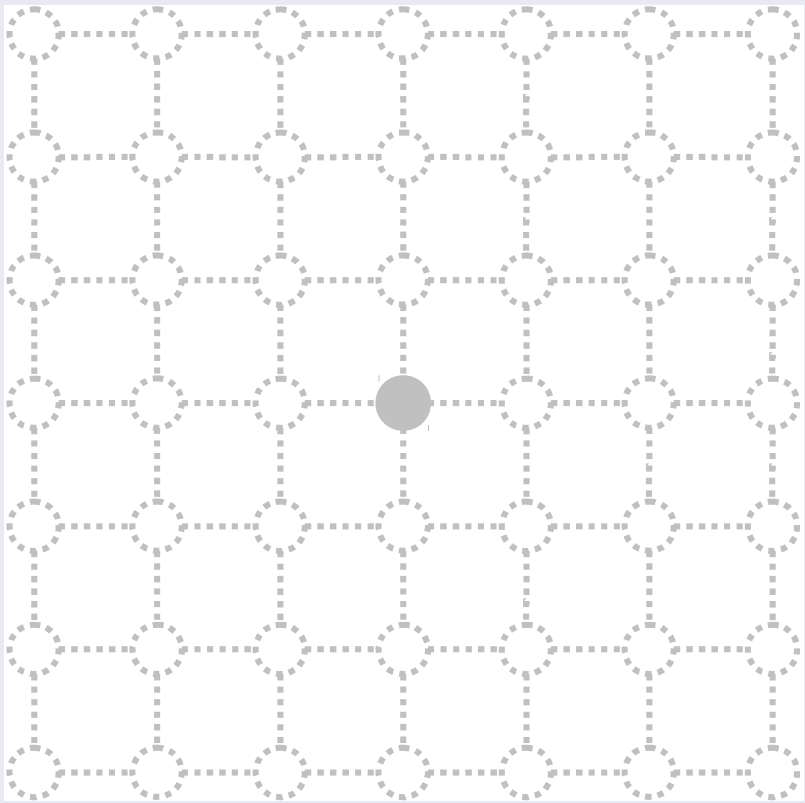
    if the node contains a goal state **then return** the corresponding solution
    add the node to the explored set
    expand the chosen node, adding the resulting node to the frontier
      only if not in the frontier and not in the explored set
  end

Search Algorithms

Graph-search on a rectangular grid problem



Search Algorithms

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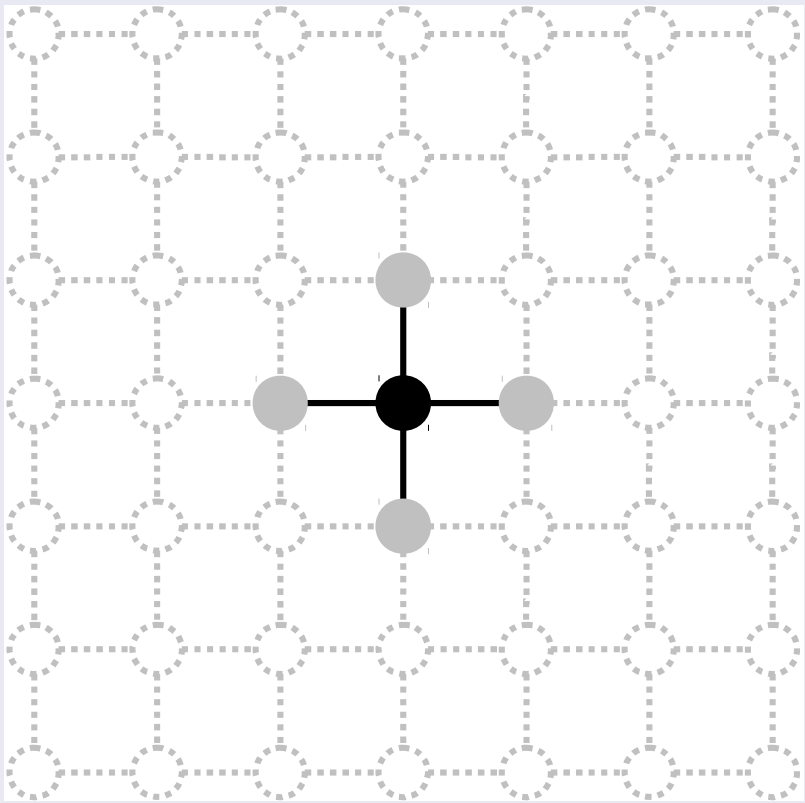

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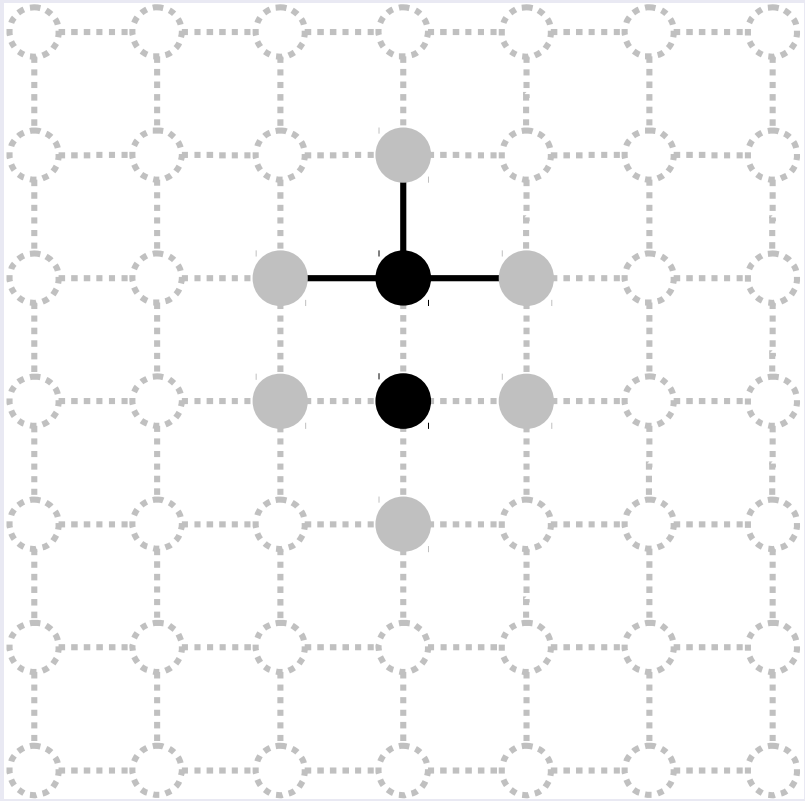

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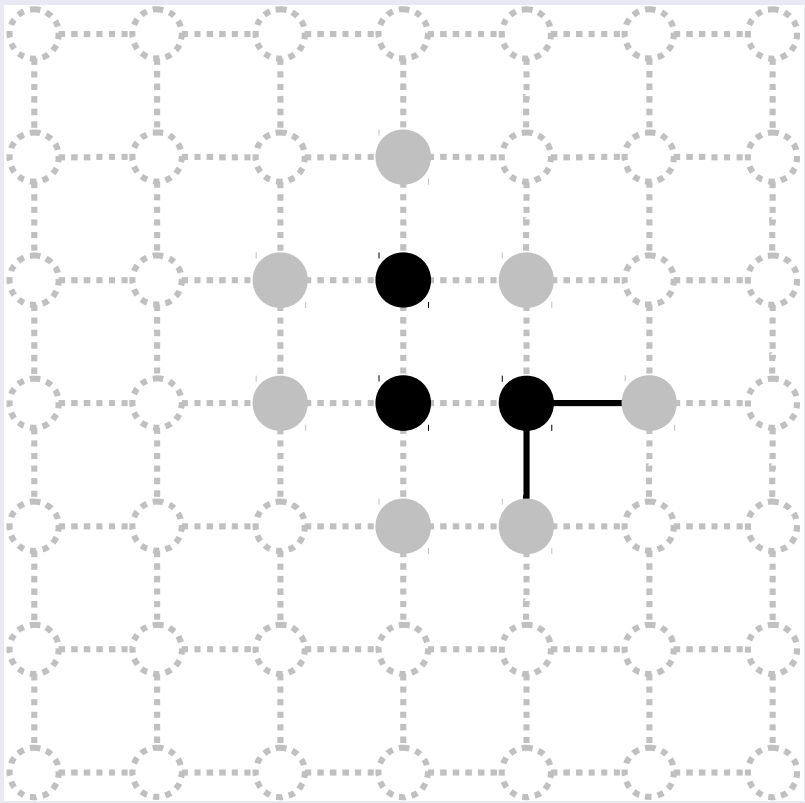

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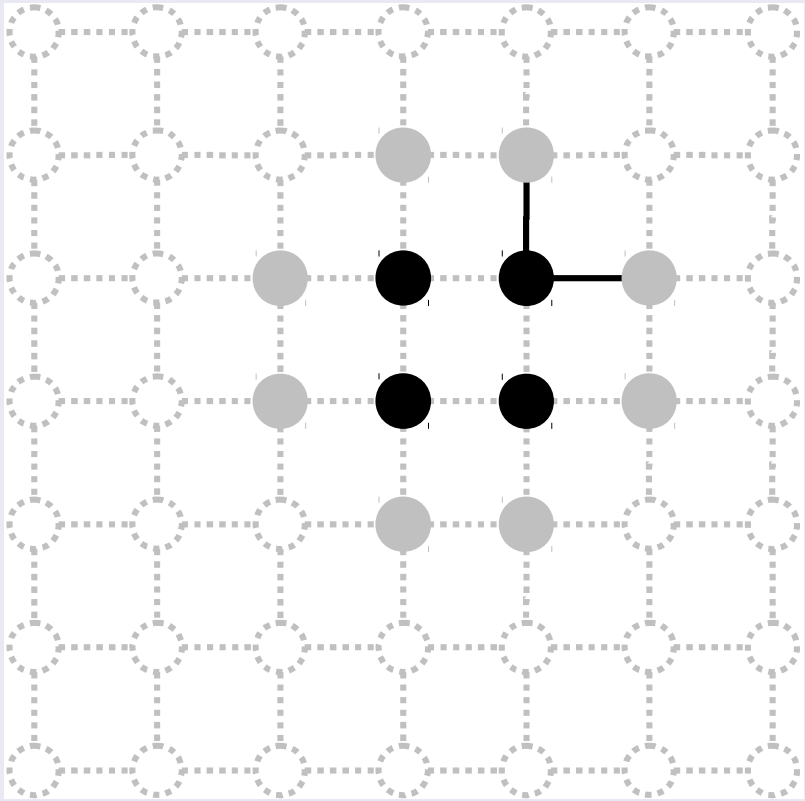

Search Algorithms

Properties of search algorithms

- The method in which a search algorithm traverses the tree is known as the ***search strategy***.

Search Algorithms

Properties of search algorithms

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- The ***search strategy*** is defined by the method used by the algorithm for ***choosing*** the next node from the frontier (a.k.a., fringe or open list).

Search Algorithms

Properties of search algorithms

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  Is the algorithm guaranteed to find a goal node, if one exists?

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- **Space complexity:**
  What is the maximum number of nodes stored in memory?

Search Algorithms

Properties of search algorithms

Time and space complexities are measured in terms of:

- Branching factor, ***b***,

Search Algorithms

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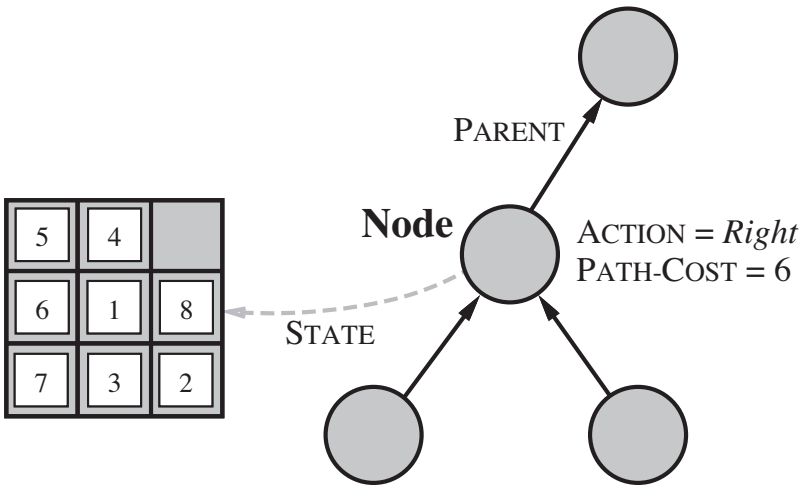
Search Algorithms

Infrastructure for search algorithms

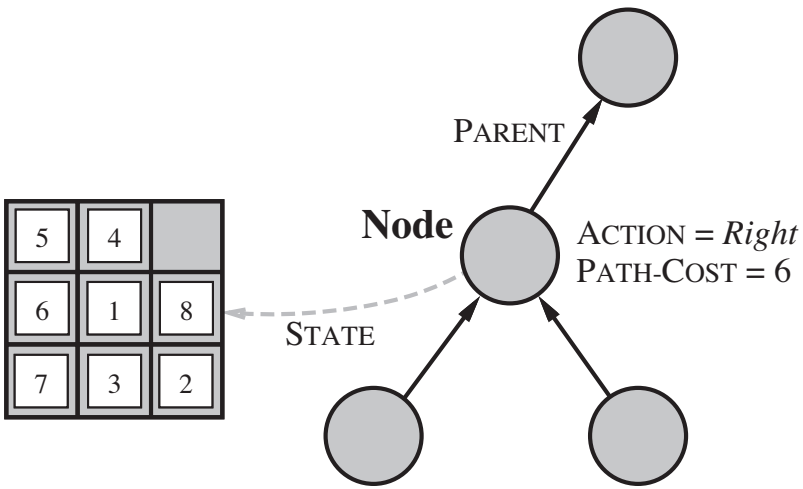
- Special data structures are needed to represent: the problem, the nodes, the frontier, and the explored states.



Search Algorithms

Infrastructure for search algorithms

- Special data structures are needed to represent: the problem, the nodes, the frontier, and the explored states.
- Each node *n* has the following components:
  - *n*.STATE, *n*.PARENT, *n*.ACTION, *n*.PATH-COST, *n*.CHILD-NODE(*problem*, *action*), and *n*.SOLUTION()



Search Algorithms

Infrastructure for search algorithms

- Each problem *p* has the following components:
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- Explored states are kept track of using a data structure that acts as a set.

Search Algorithms

Types of search algorithms

- **Uninformed Search:**
  Only has the information provided by the problem formulation (initial state, available actions, transition model, goal test, and step/path cost),

Search Algorithms

Types of search algorithms

- **Uninformed Search:**
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- **Informed Search:**
  Has additional information that allows it to judge the promise of an action, i.e. the estimated cost from a state to a goal.

Outline

Uninformed Search

Uninformed Search algorithms

- Breadth-first search (BFS),
- Uniform-cost search,
- Depth-first search (DFS),
- Depth-limited search,
- Iterative deepening search (IDS),

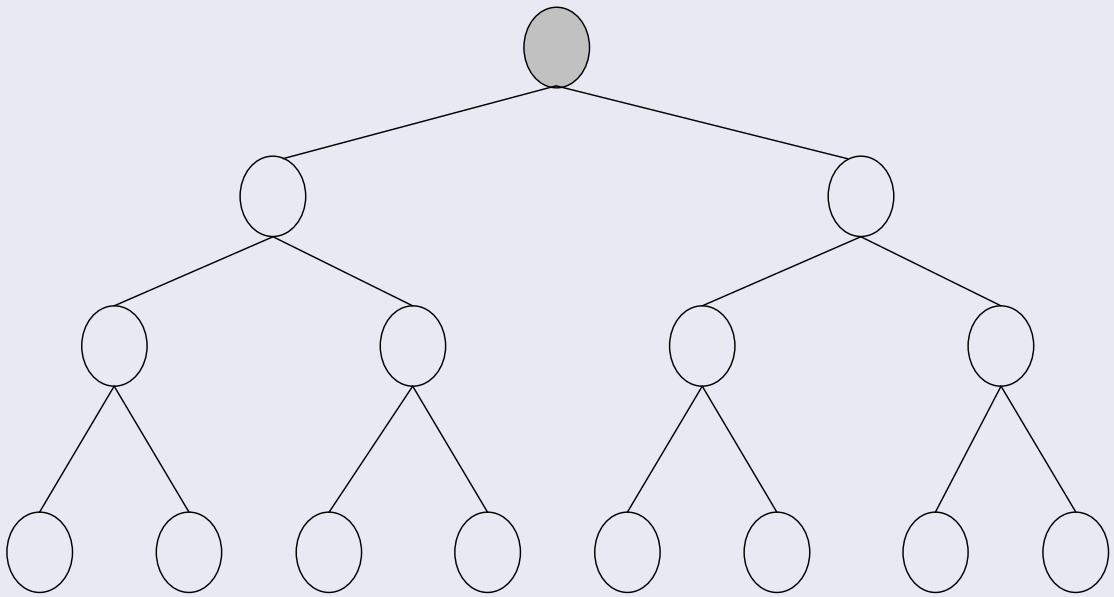
Uninformed Search

Breadth-first search

- The frontier is implemented as a FIFO queue,
- The tree is traversed on a level-by-level basis.

Uninformed Search

Breadth-first search



Uninformed Search

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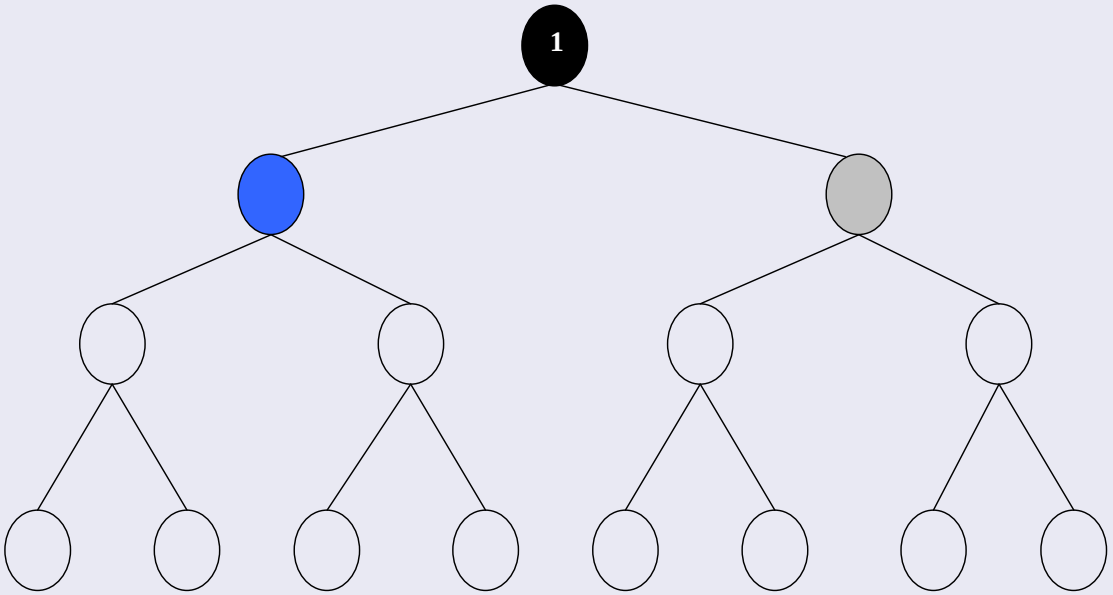

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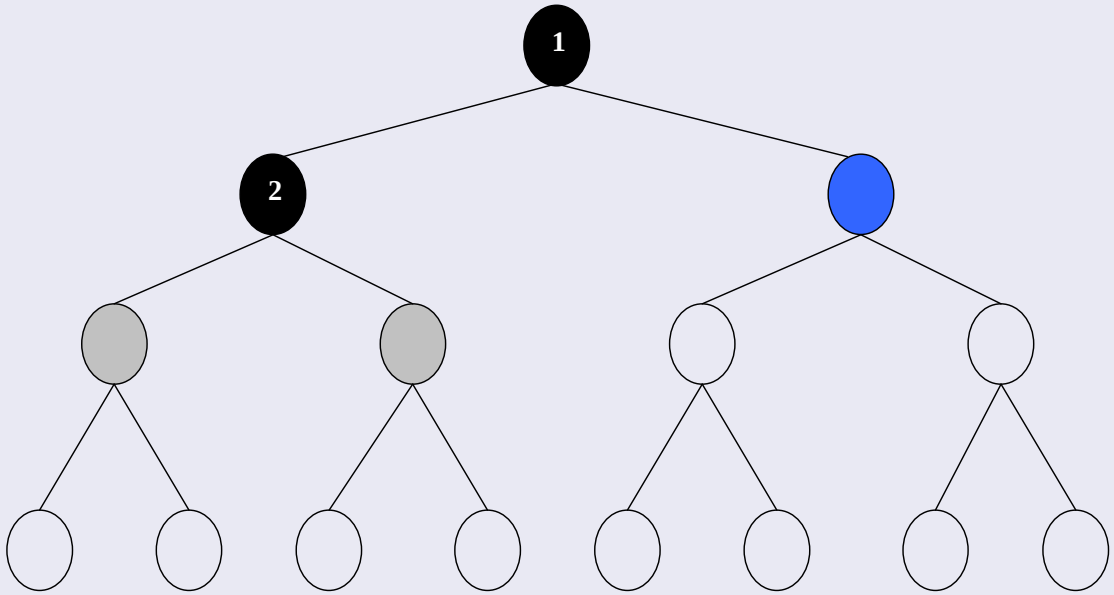

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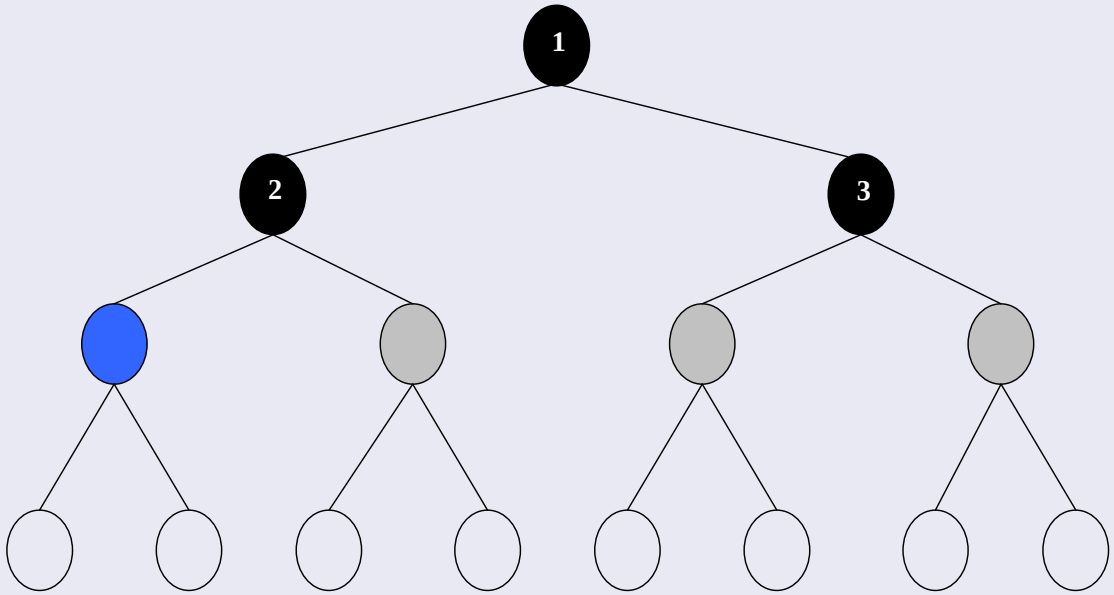

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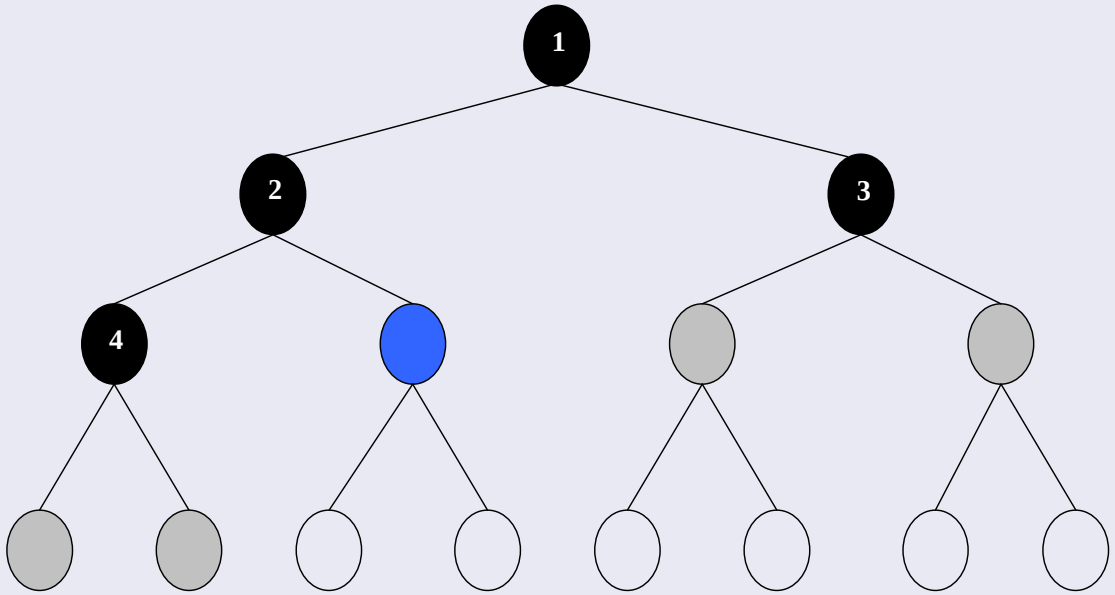

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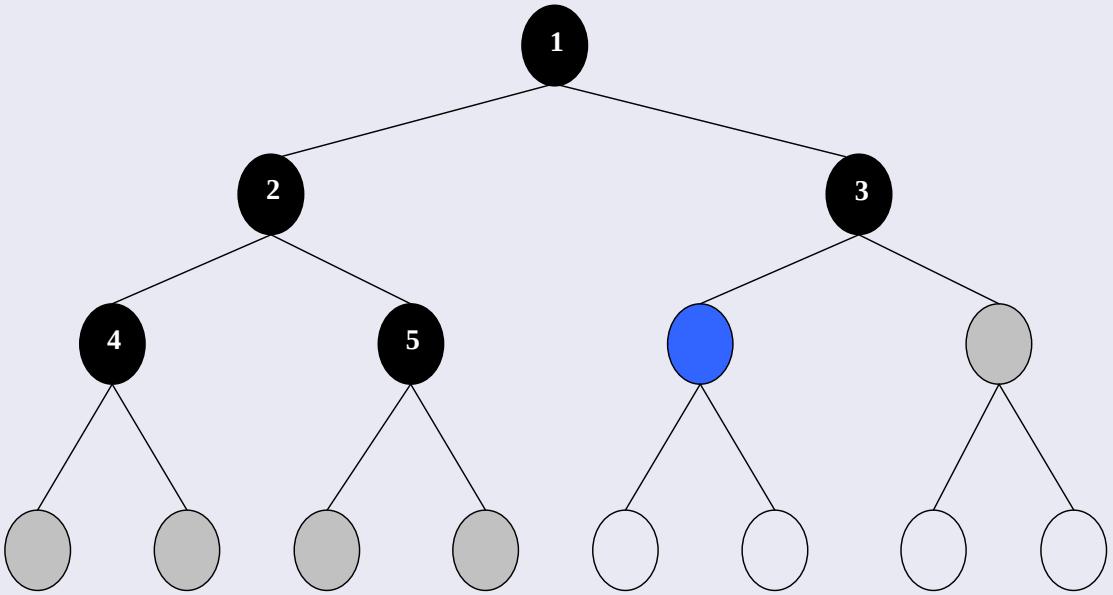

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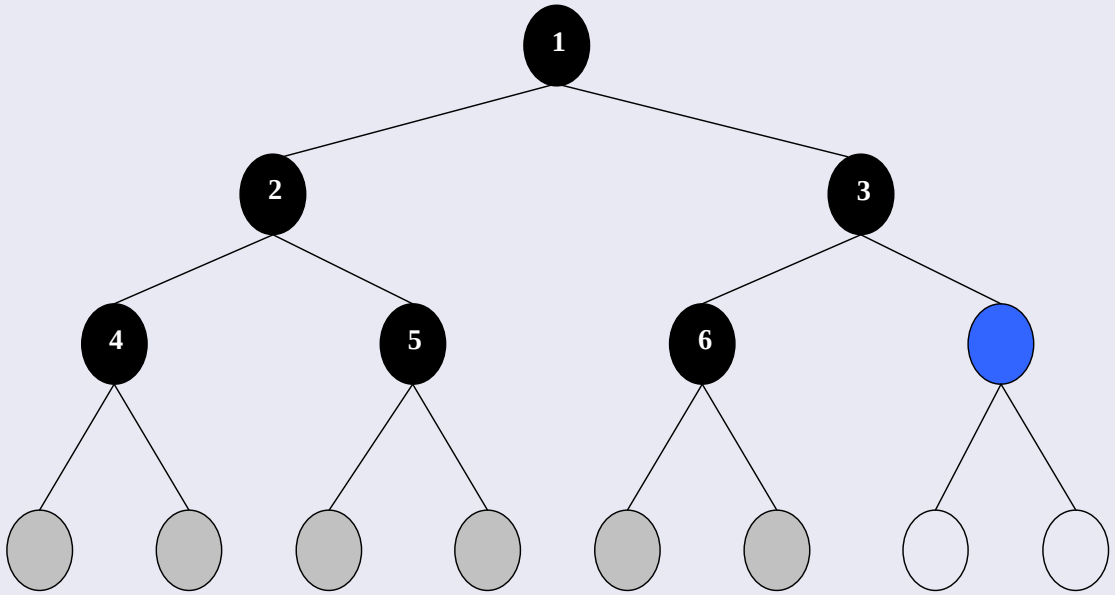

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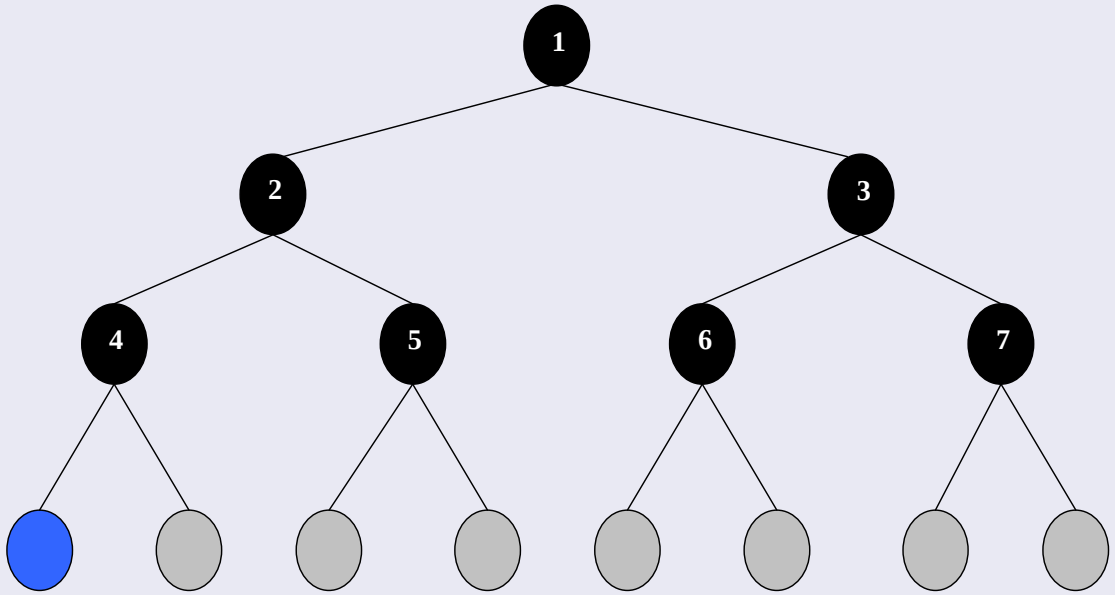

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function BREADTH-FIRST-SEARCH(problem) returns a solution, or failure
  node ← a node with STATE=problem.INITIAL-STATE, PATH-COST=0
  if problem.GOAL-TEST(node.STATE) then return node.SOLUTION()
  frontier ← a FIFO queue with node as the only element
  loop do
    if frontier.EMPTY?() then return failure
    node ← frontier.POP()          /* choose shallowest node in frontier */
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    for each action in problem.ACTIONS(node.STATE) do
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      if problem.GOAL-TEST(child.STATE) then return child.SOLUTION()
      frontier.INSERT(child)
```

Search Algorithms

Breadth-first search (graph version)

```
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  node ← a node with STATE=problem.INITIAL-STATE, PATH-COST=0
  if problem.GOAL-TEST(node.STATE) then return node.SOLUTION()
  frontier ← a FIFO queue with node as the only element
  explored ← an empty set
  loop do
    if frontier.EMPTY?() then return failure
    node ← frontier.POP()              /* choose shallowest node in frontier */
    add node.STATE to explored
    for each action in problem.ACTIONS(node.STATE) do
      child ← node.CHILD-NODE(problem, action)
      if child.STATE is not in explored and not in frontier then
        if problem.GOAL-TEST(child.STATE) then return child.SOLUTION()
        frontier.INSERT(child)
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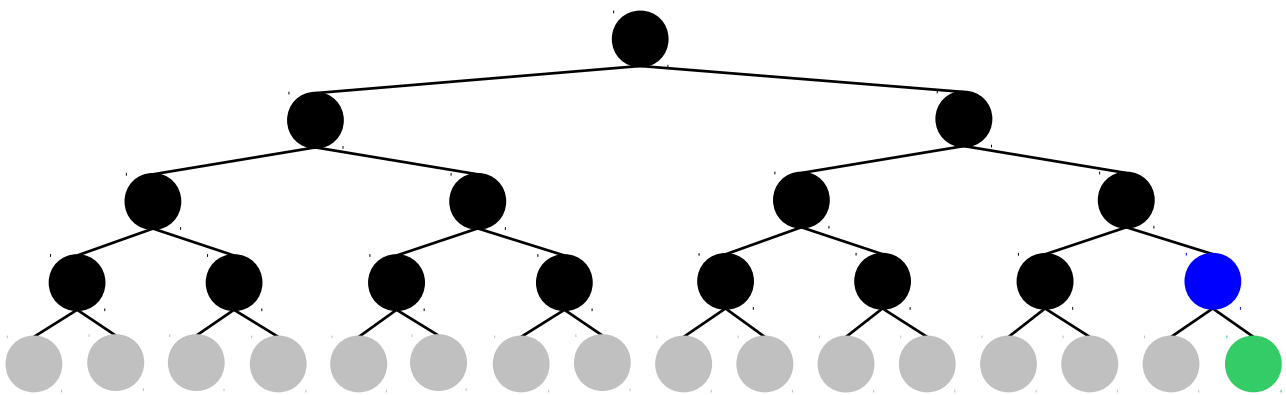
BFS properties:

- Upper-bound case: when the goal node is the last node at depth d:



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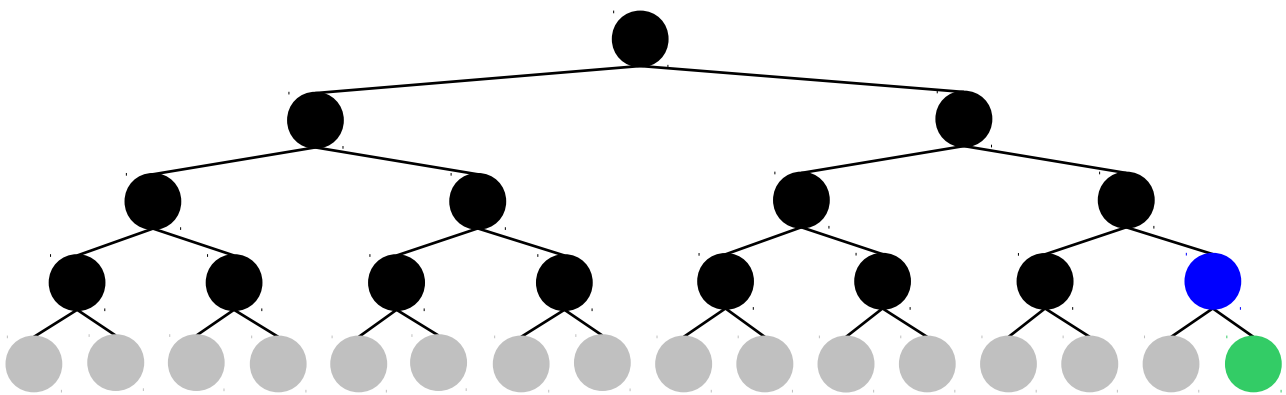

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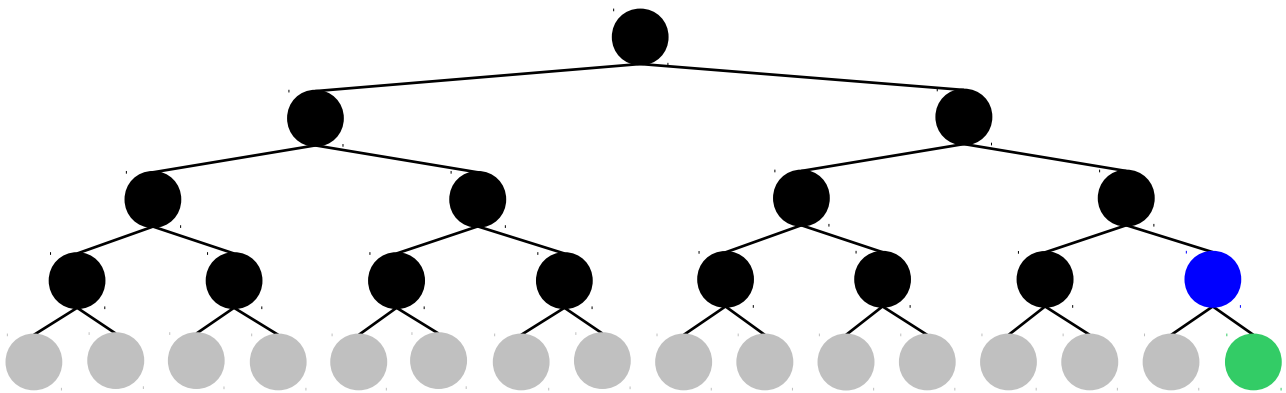

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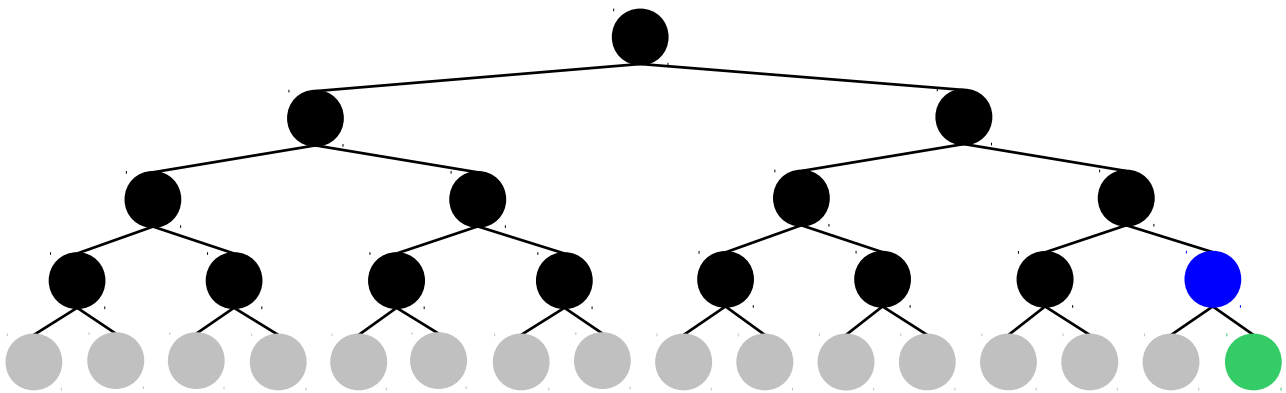
  - Space and time complexity: all generated nodes.



Outline

Requirements

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- Build the search tree up to a given depth.
- Traverse the search tree according to a given strategy.
- Answer descriptive questions.

Reading Material

Which parts of the textbook are covered

- Russell-Norvig, Chapters 3:
  - Pages 64 - 83.