CSE 411: Artificial Intelligence (Elective Course #6)

400 Level, Mechatronics Engineering
2nd Term 2016/2017, Lecture #3

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March 13th, 2017

Credits to Dr. Mohamed El Abd for the slides

Adminstrivia

Notes

- Assignment #1:
  - Released today.
  - Due: Monday, March 20, 2017
  - Formulate two problems in Python.
  - Email Python files and hand in a printout!

Course Info:

- Website: http://hshehata.github.io/courses/zu/cse411/
- Office hours: Sunday 11:30am - 12:30pm

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- ”Requirements & Reading Material” section:
  - Page numbers are based on 3rd US edition of AIMA.
  - Full TOC: http://aima.cs.berkeley.edu/contents.html.

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Outline

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Problem solving by searching

Introduction

- One approach to solve any problem is to formulate it in ***STATE-SPACE*** representation.

Problem solving by searching

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- The problem is well-defined by defining:
  - An initial state.
  - A set of actions.
  - A transition model.
  - A goal test.
  - A concept of cost: step and path cost.

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- The problem is well-defined by defining:
  - An initial state.
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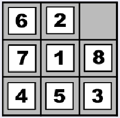
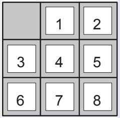
  - A transition model.
  - A goal test.
  - A concept of cost: step and path cost.
- This is used to build a search tree to be traversed by a tree-search (or graph-search) algorithm.

Problem solving by searching

A puzzle example





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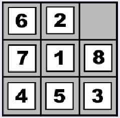

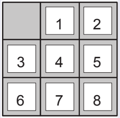

- **Initial state:** any arrangement of tiles.

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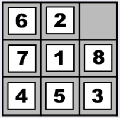

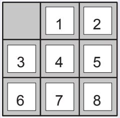

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Problem solving by searching

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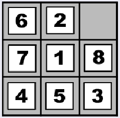

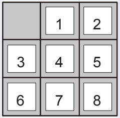

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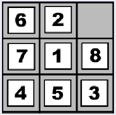
- **Path cost:** each step costs 1, so path cost is the number of steps along the path.

Problem solving by searching

A puzzle search tree



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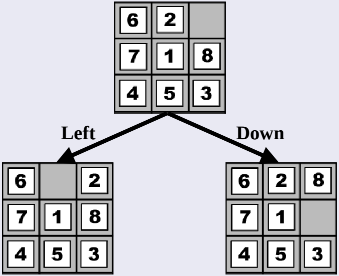

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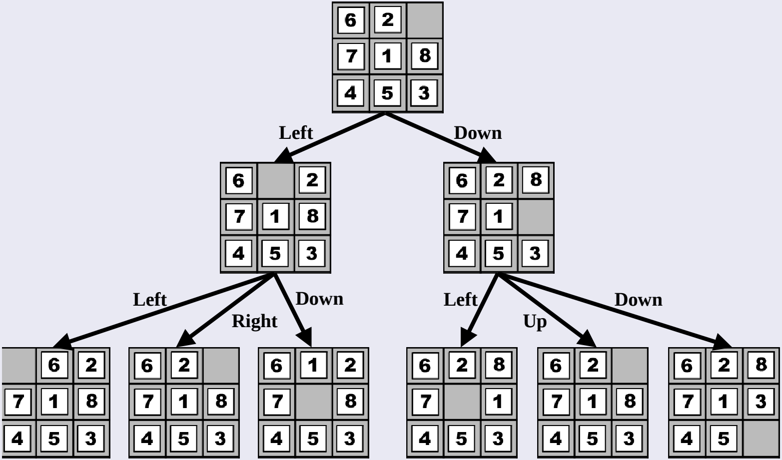

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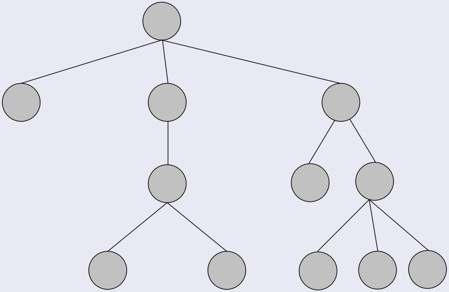

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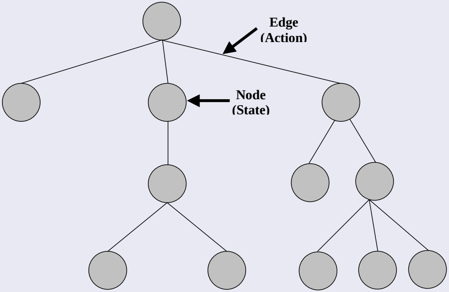

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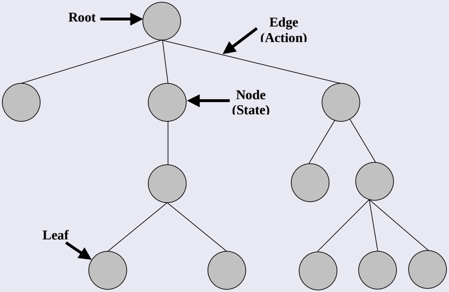

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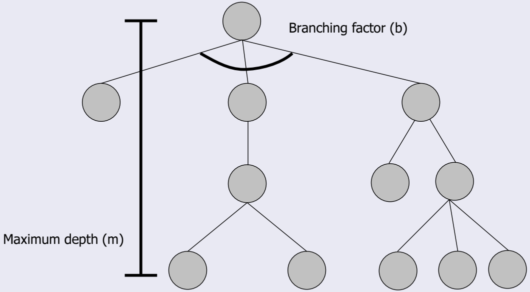

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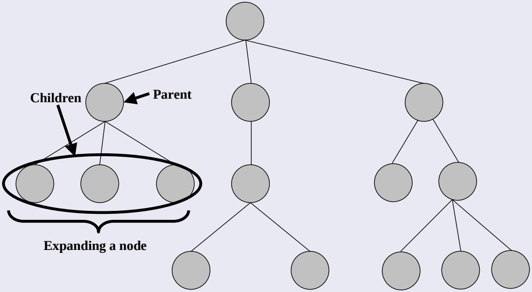

Search Algorithms

General tree-search algorithm

TREE-SEARCH(*problem*) **returns** a solution, or failure

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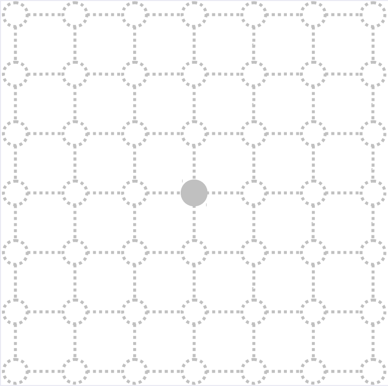
Search Algorithms

Tree-Search on a rectangular grid problem



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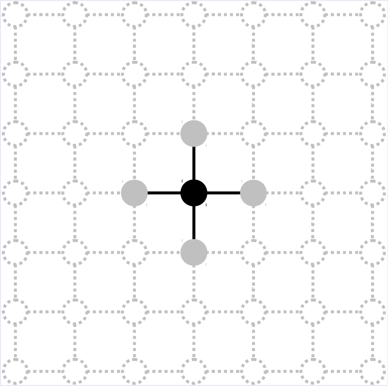

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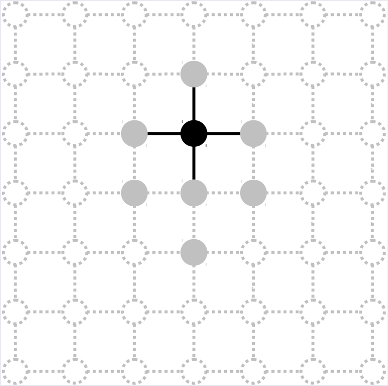

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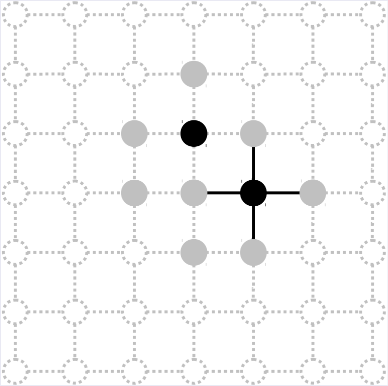

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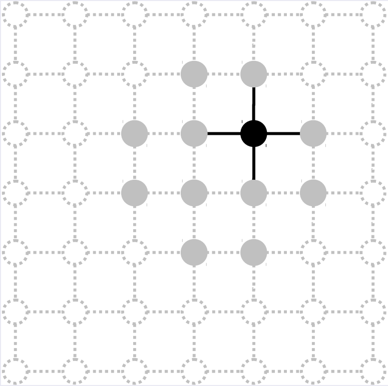
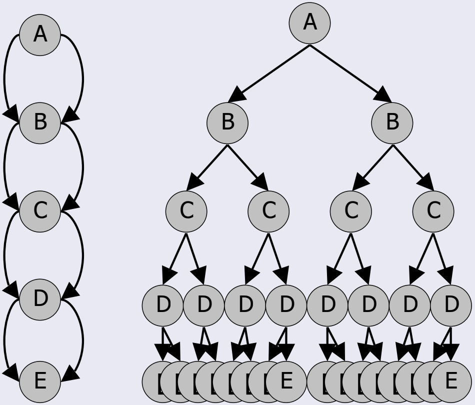


Search Algorithms

Multiple paths to the same state



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- The tree search algorithm becomes a graph search algorithm.

Search Algorithms

General graph-search algorithm

GRAPH-SEARCH(*problem*) **returns** a solution, or failure
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  loop do
    if the frontier is empty **then return** failure
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    expand the chosen node, adding the resulting node to the frontier
      ...
  end

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General graph-search algorithm

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    if the node contains a goal state **then return** the corresponding solution
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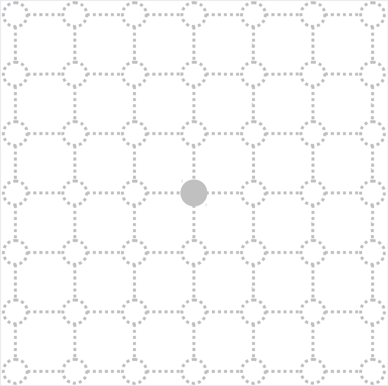
    expand the chosen node, adding the resulting node to the frontier
      only if not in the frontier and not in the explored set
  end

Search Algorithms

Graph-search on a rectangular grid problem



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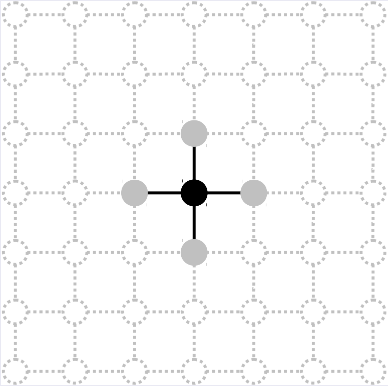

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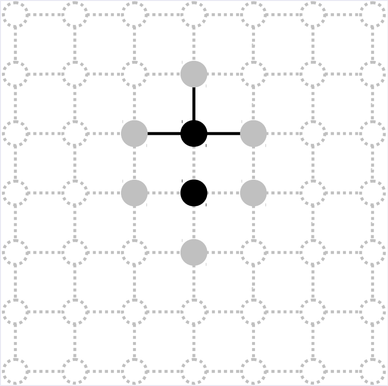

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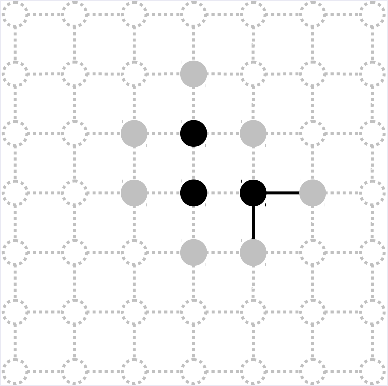

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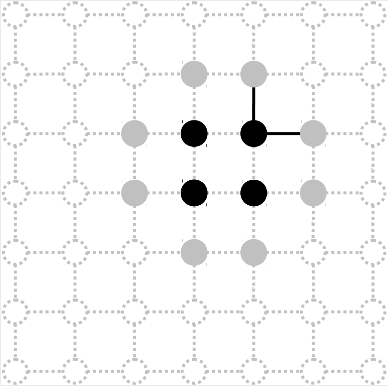

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Properties of search algorithms

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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).

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- **Time complexity:**
  How many nodes are generated?
- **Space complexity:**
  What is the maximum number of nodes stored in memory?

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Time and space complexities are measured in terms of:

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Time and space complexities are measured in terms of:

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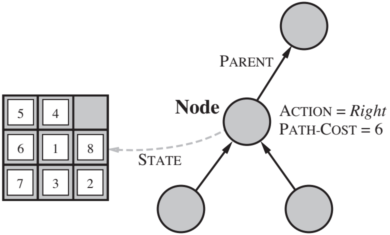
- Maximum depth of the search tree, ***m***,

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

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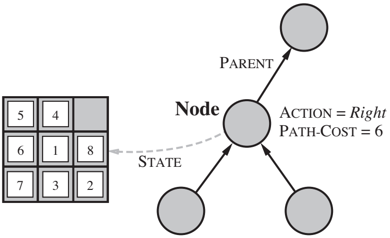
- Special data structures are needed to represent: the problem, the nodes, the frontier, and the explored states.
- Each node *n* has the following components:
  - *n*.STATE, *n*.PARENT, *n*.ACTION, *n*.PATH-COST, *n*.CHILD-NODE(*problem*, *action*), and *n*.SOLUTION()



Search Algorithms

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- 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.

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Types of search algorithms

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

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

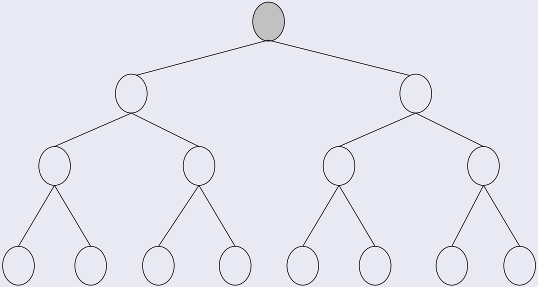
Uninformed Search

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



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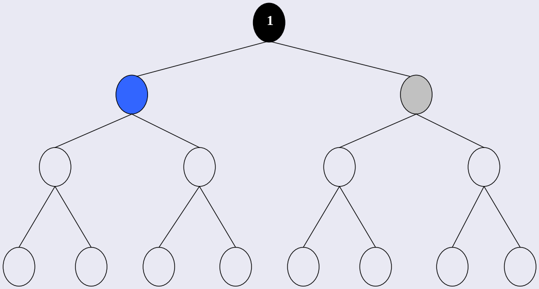

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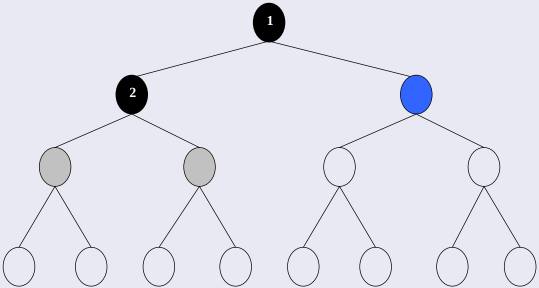

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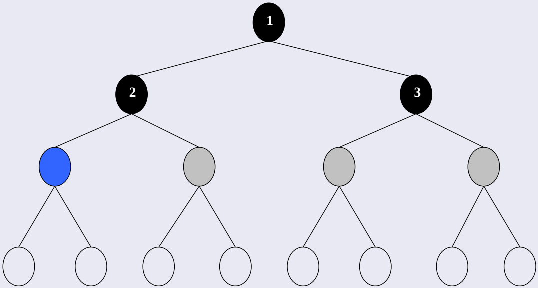

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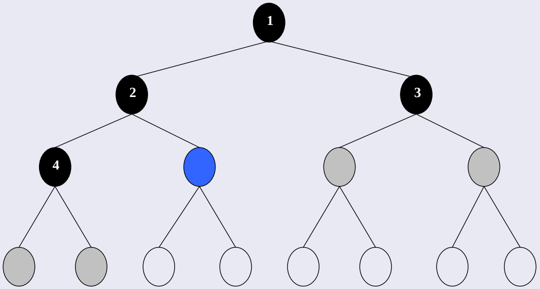

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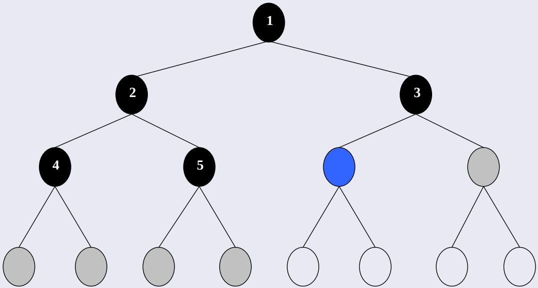

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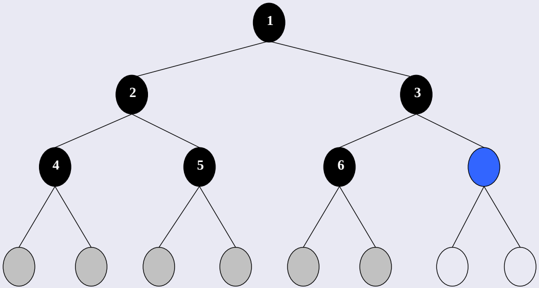

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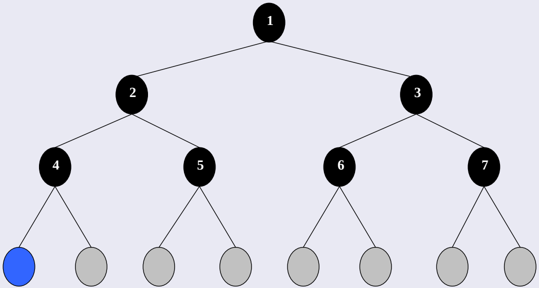

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  frontier ← a **FIFO queue** with *node* as the only element

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Breadth-first search (tree version)

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

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    for each *action* **in** *problem*.ACTIONS(*node*.STATE) **do**

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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 */
    for each action in problem.ACTIONS(node.STATE) do
      child ← node.CHILD-NODE(problem, action)
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    for each *action* **in** *problem*.ACTIONS(*node*.STATE) **do**
      child ← *node*.CHILD-NODE(*problem*, *action*)
      if *problem*.GOAL-TEST(*child*.STATE) **then return** *child*.SOLUTION()
      frontier.INSERT(*child*)

Search Algorithms

Breadth-first search (graph version)

```
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
  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)
```

Uninformed Search

Breadth-first search

BFS properties:

- Complete (if b is finite).

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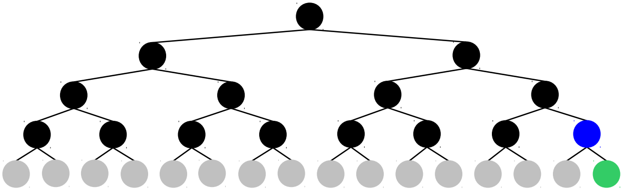
- Upper-bound case: when the goal node is the last node at depth d:



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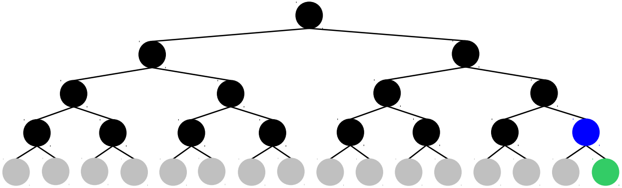

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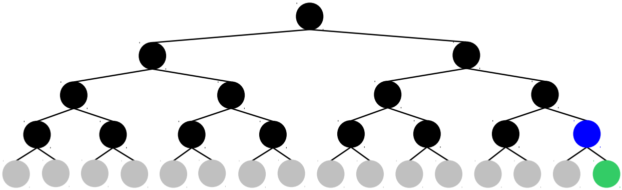

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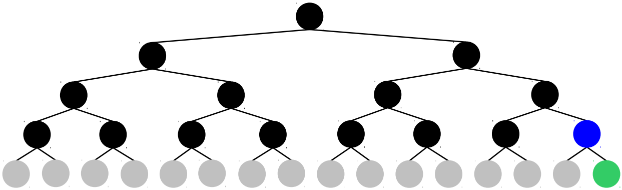
  - Space and time complexity: all generated nodes.



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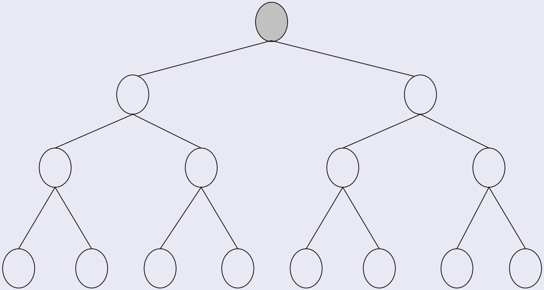
- Algorithm always expands deepest unexpanded node in current frontier.
- Once a leaf is reached, the search backs up (*i.e.*, backtracks) to the next deepest node that still has unexplored successors.
- Search continues until reaching the goal or no frontier nodes are left for expansion.

Uninformed Search

Depth-first search



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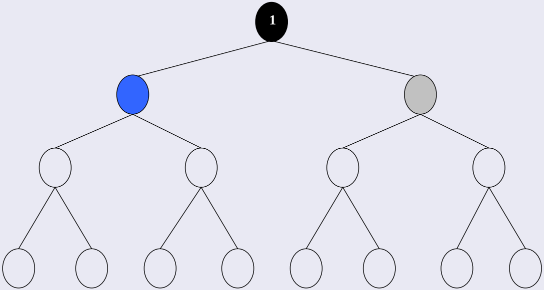

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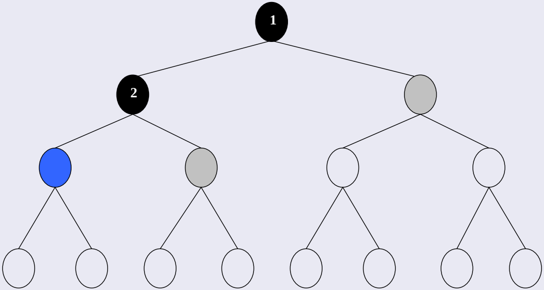

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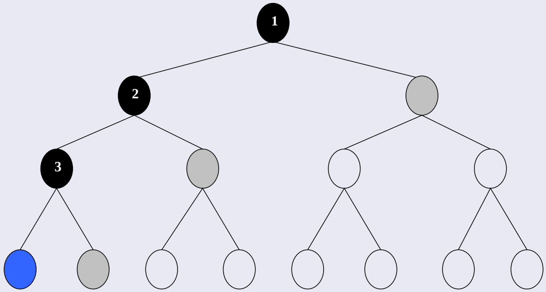

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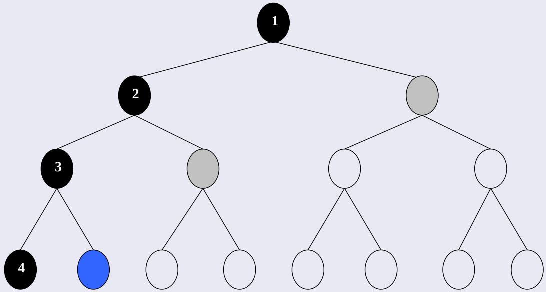

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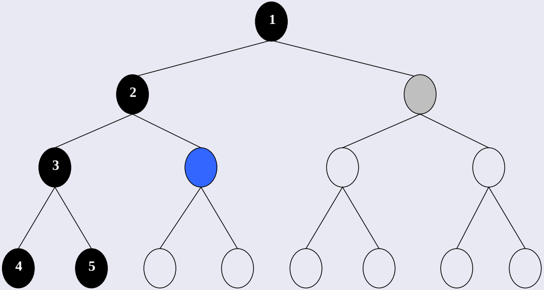

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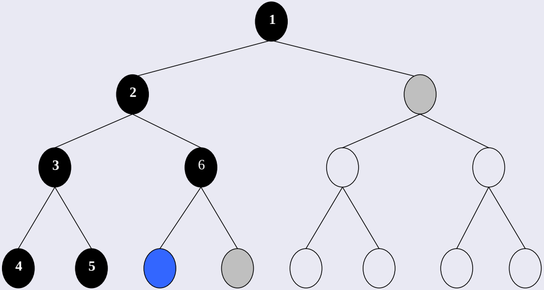

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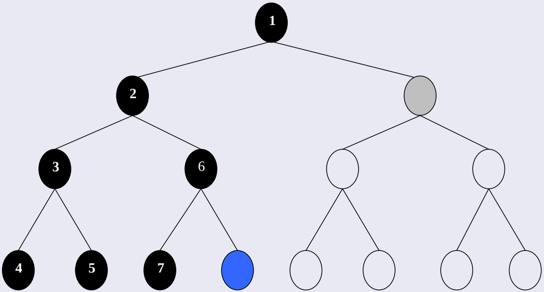

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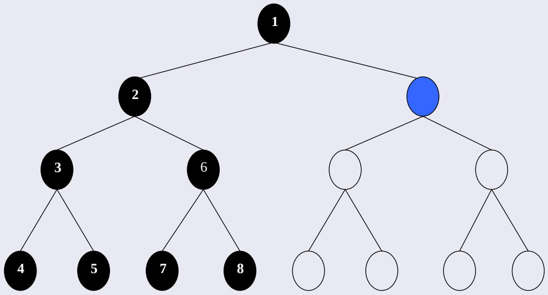

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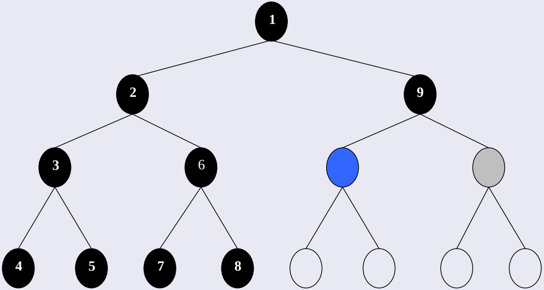

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DFS properties:

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DFS properties:

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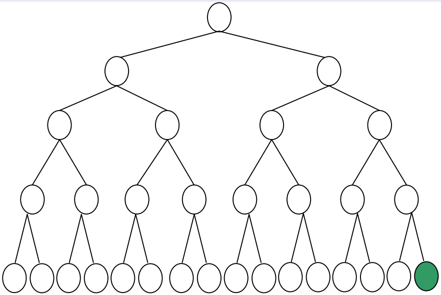

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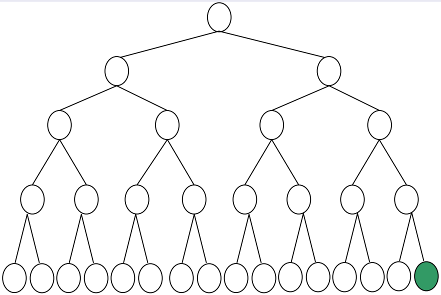

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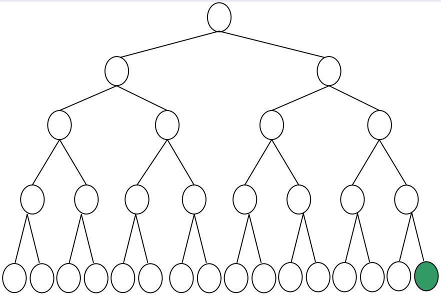

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DFS properties:

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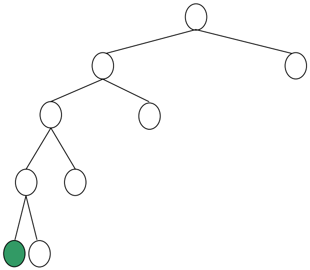

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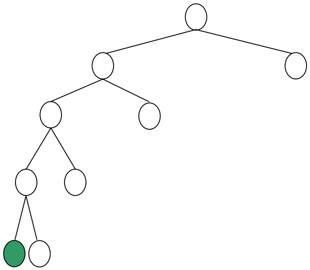

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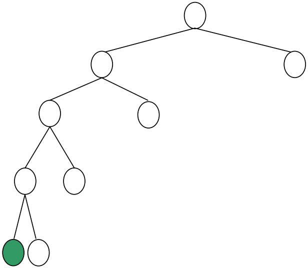

Outline

Requirements

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- When given a certain problem you should be able to:
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  - 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 75 - 83.
  - Pages 85 - 87.