CS 3011: Artificial Intelligence

Solving Problems by Searching

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Problem-Solving Agents

- This is a kind of goal-based agents that try to find a sequence of actions to achieve a goal.
  - Sometimes an action directly achieves a goal; sometimes a series of actions are required
- Finding this sequence of actions is called search

Example: Traveling in Romania

- Suppose the agent is currently in the Arad and has to reach Bucharest .
- Goal: Reach Bucharest on time

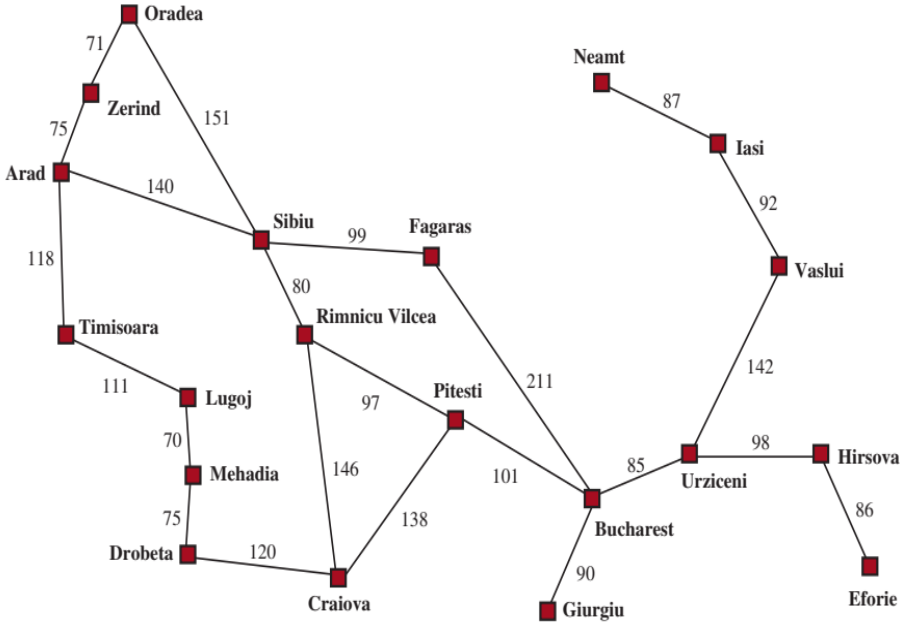
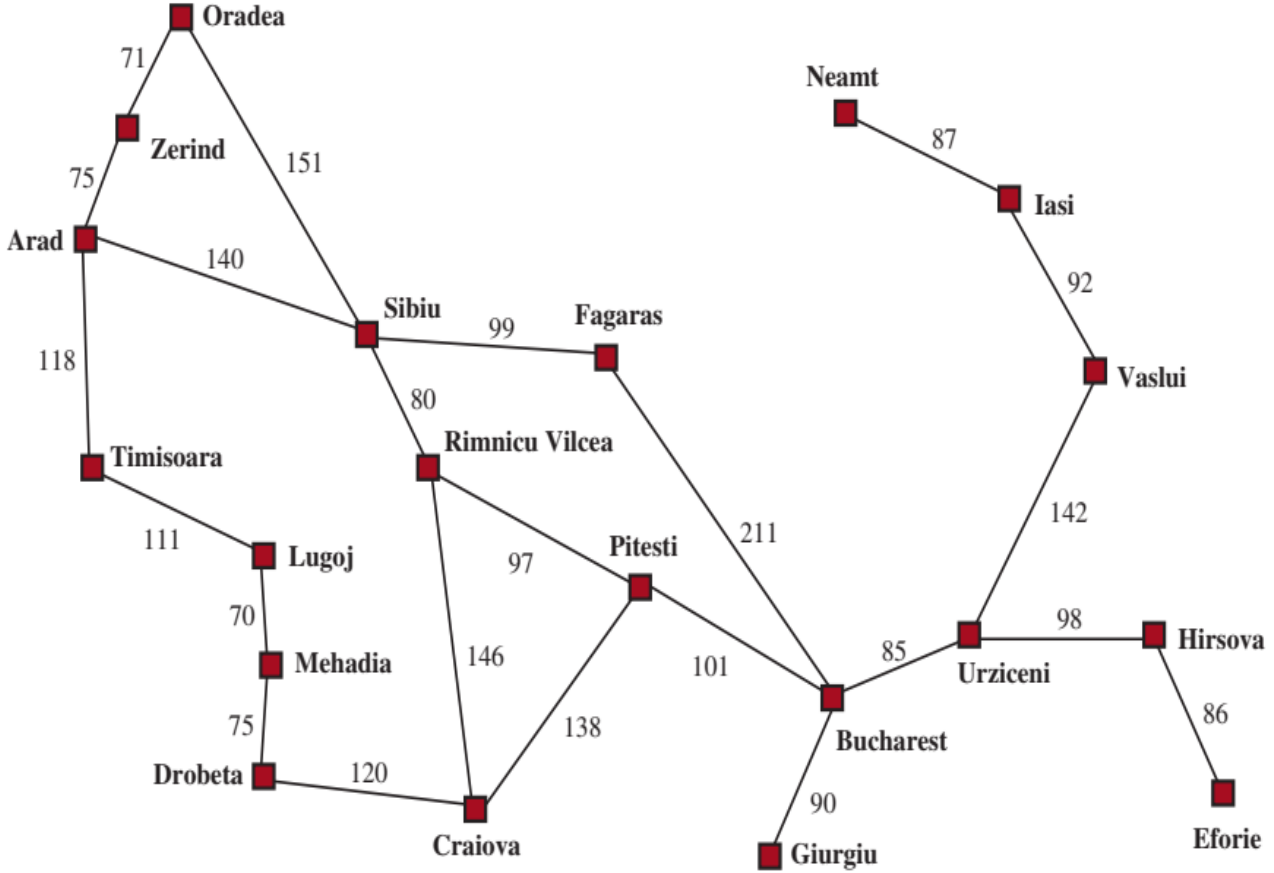


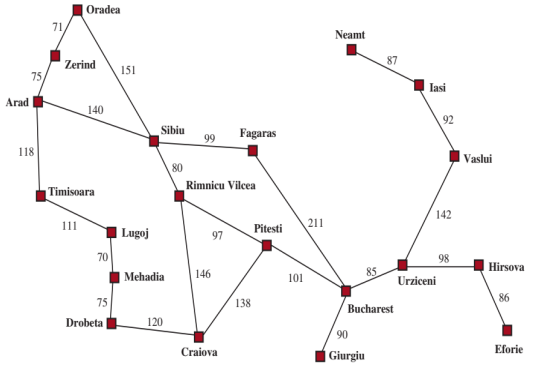
Figure: A simplified road map of part of Romania, with road distances in miles.

Example: Traveling in Romania



Search problems and solutions

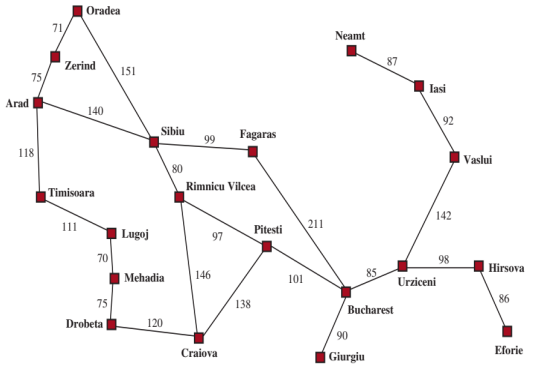
A search **problem** can be defined formally by these components:



- The initial state that the agent starts in. Example: *Arad*.
- A description of possible actions available to the agent. Given a state s, ACTIONS(s) returns a finite set of actions that can be executed in s.
  - Example: ACTIONS(Arad) = {ToSibiu, ToTimisoara, ToZerind}
- A transition model, which describes what each action does. RESULT(s,a) returns the state (successor) that results from doing action a in state s.
  - Example: RESULT(Arad, ToZerind) = Zerind

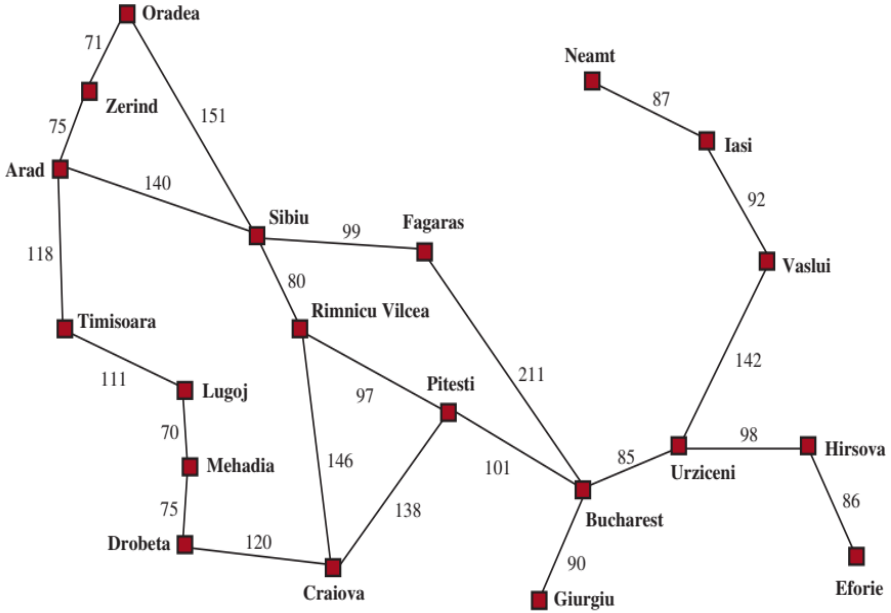
Search problems and solutions…

- The goal test, which determines whether a given state is a goal state
  - Example: Goal state= Bucharest
- path cost: function assigns numeric cost to each path
  - A sequence of actions forms a path.



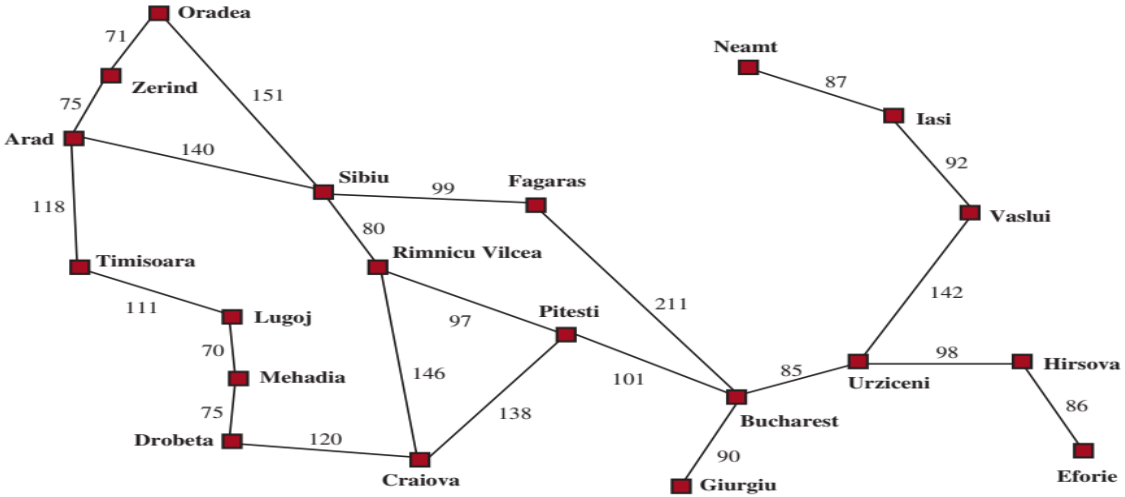
state space in Search problems

- state space: The set of all states reachable from the initial state by any sequence of actions.
  - The initial state, actions, and transition model implicitly define the state space of the problem.
  - The state space forms a directed network (graph) in which the nodes are states, and the links are actions



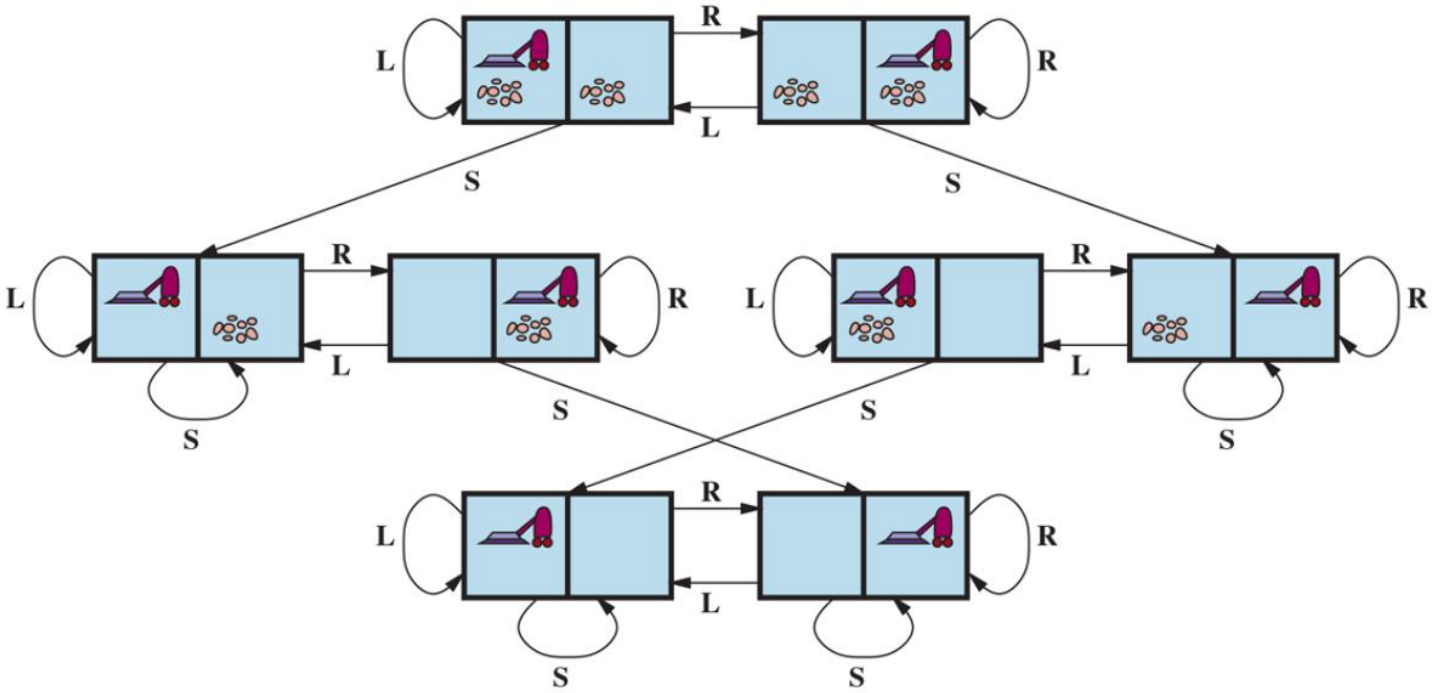
Optimal solution

- A solution to problem is a path from the initial state to a goal state.
  - Solution quality is measured by the path cost function.
- An optimal solution has the lowest path cost among all solutions.



Sample Search Problem

Vacuum World State Space Graph



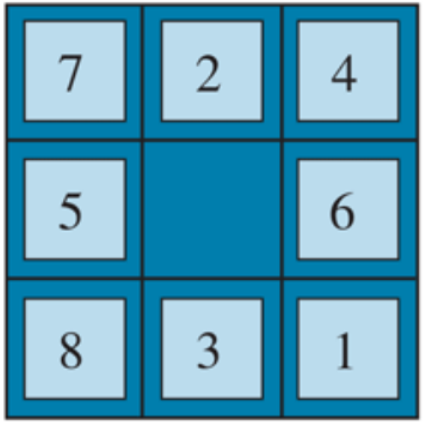
The state-space graph for the two-cell vacuum world. There are 8 states and three actions for each state: L = *Left*, R = *Right*, S = *Suck*.

Formulating the Vacuum World Problem

- States: The state is determined by both the agent location and dirt locations. The agent is in one of the two locations, each of which might or might not contain dirt.
  - Possible world states= 2*2^2= 8
- Initial state: Any state may be designated as initial state
- Actions: Left, Right, and Suck
- Transition model: The actions have expected effects, except that moving Left in leftmost square, moving Right in rightmost square, and Sucking in a clean square have no effect.
- Goal State: Check whether all the squares are clean.
- Path Cost: Each cost 1, so the path cost is the number of steps in the path

Example: The 8-puzzle

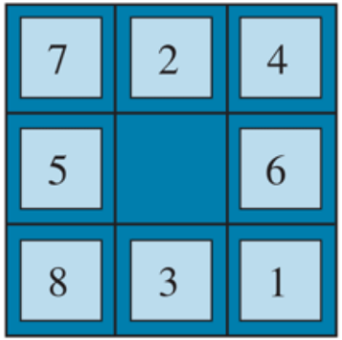
- States?
- Initial state?
- Actions?
- Goal test?
- Path cost?



Start State

Goal State

Example: The 8-puzzle



Start State

Goal State

- States? locations of tiles
- Actions? move blank left, right, up, down
- Goal test? = goal state (given)
- Path cost? 1 per move

[Note: optimal solution of *n*-Puzzle family is NP-hard]

What exactly is “ Searching for Solution”?

- A solution is an action sequence
  - Search algorithms work by considering various action sequences.
- The possible action sequences, starting at the initial state form a search tree with
  - The initial state at the root
  - The branches are the actions, and
  - The nodes correspond to states in the state space of the problem
- The essences for search
  - Following up one option now and putting others aside for later, in case the first choice does not lead to a solution

Nodes in search Tree

- Node n is a data structure that keep track of

n.STATE: the state in the state space to which the node corresponds.

n.PARENT: the node in the search tree that generated this node.

n.ACTION: the action that was applied to the parent to generate the node.

n.PATH-COST: the total cost of the path (i.e., g(n)) from the initial state to this node.

A general Tree search algorithm

```
function TREE-SEARCH(problem) returns a solution, or failure
    initialize the frontier using the initial state of 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 nodes to the frontier
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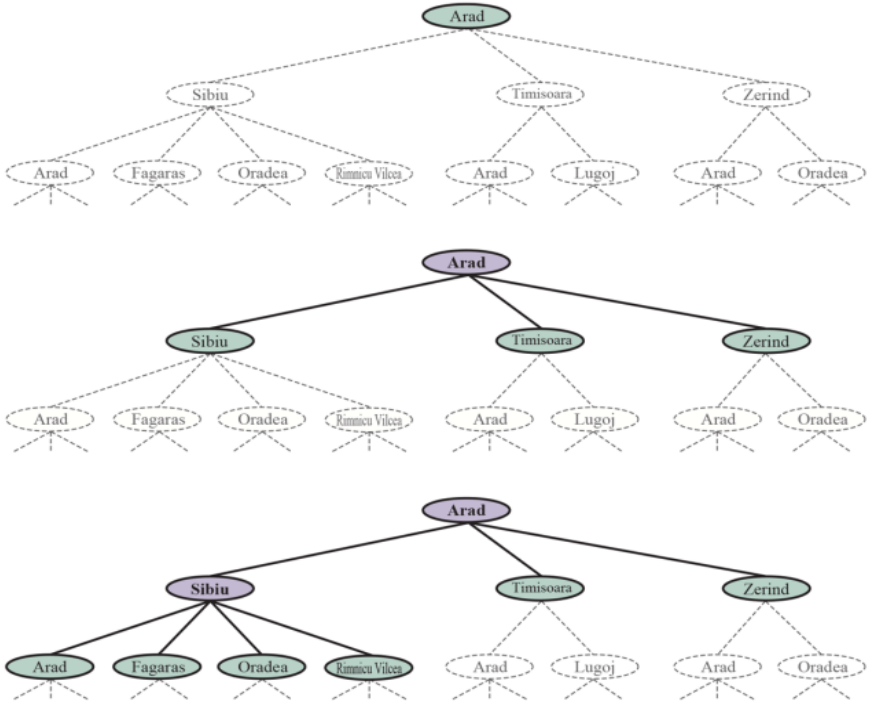

Three partial search trees for finding a route from Arad to Bucharest. Nodes that have been *expanded* are lavender with bold letters; nodes on the frontier that have been *generated* but not yet expanded are in green; the set of states corresponding to these two types of nodes are said to have been *reached*. Nodes that could be generated next are shown in faint dashed lines. Notice in the bottom tree there is a cycle from Arad to Sibiu to Arad; that can't be an optimal path, so search should not continue from there.

A general Graph search algorithm

function GRAPH-SEARCH(*problem*) **returns** a solution, or failure
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    choose a leaf node and remove it from the frontier
    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 nodes to the frontier
      only if not in the frontier or explored set

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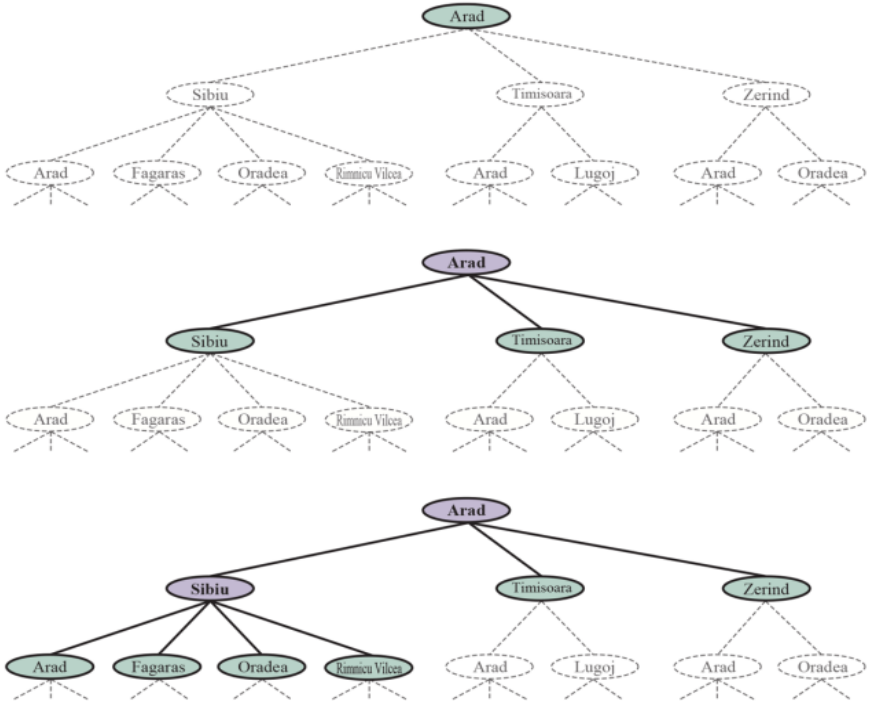

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Search Strategies

- A search strategy is defined by picking the order of node expansion
- Strategies are evaluated along the following dimensions:
  - Completeness: Does it always find a solution if one exists?
  - Time complexity: Number of nodes generated
  - Space complexity: Maximum number of nodes in memory
  - Optimality: Does it always find a least-cost solution?
- Time and space complexity are measured in terms of
  - *b:* maximum no. of successors of any node
  - *d:* depth of the shallowest goal node
  - *m*: maximum length of any path in the state space.

Artificial Intelligence

Uninformed Search

28 August 2023

Uninformed Search Strategies

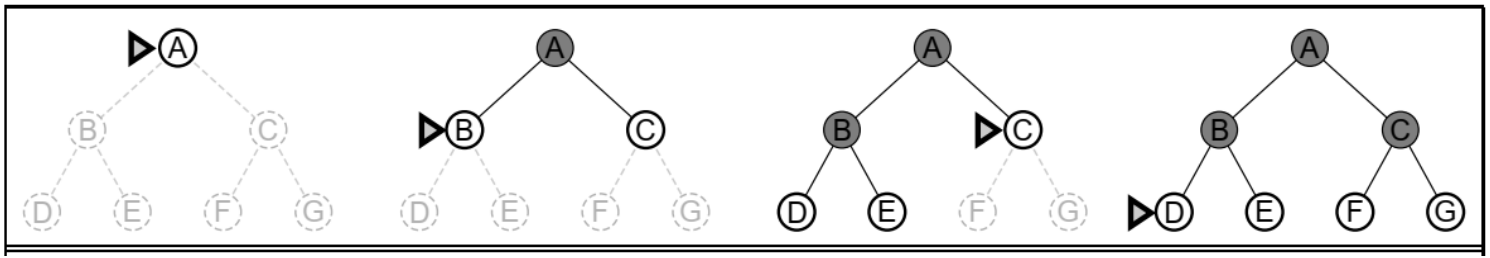
- It is also called **blind search**
- Uninformed search strategies use only the information available in the problem definition
- All they can do is generate successors and distinguish a goal state from a nongoal state.
  - Breadth-first search
  - Uniform-cost search
  - Depth-first search
  - Depth-limited search
  - Iterative deepening search

Breadth-first search

- Breadth-first search is a simple strategy in which the root node is expanded first
  - then all the successors of the root node are expanded next, then their successors, and so on
- In general, all the nodes are expanded at a given depth in the search tree before any nodes at the next level are expanded.
  - Expand shallowest unexpanded node
- Implementation:
  - This is achieved very simply by using a FIFO queue for the frontier.

Breadth-first search

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



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