Lecture 5:
Breadth-first search

Artificial Intelligence
CS-GY-6613-I

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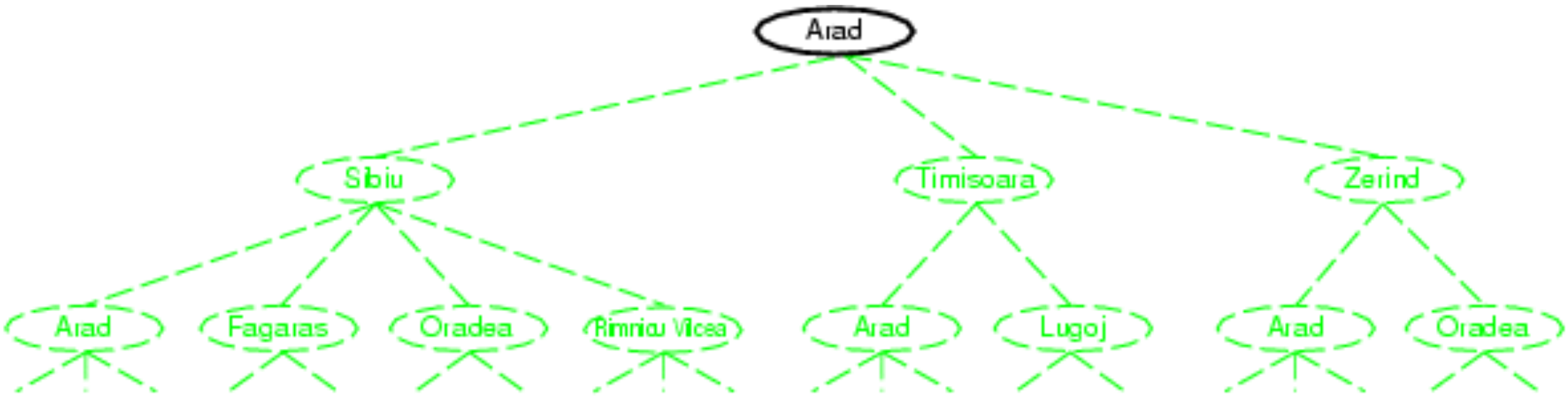
Tree search

- offline, simulated exploration of state space by generating successors of already-explored states (a.k.a.~expanding states)

```
function TREE-SEARCH( problem, strategy) returns a solution, or failure
    initialize the search tree using the initial state of problem
    loop do
        if there are no candidates for expansion then return failure
        choose a leaf node for expansion according to strategy
        if the node contains a goal state then return the corresponding solution
        else expand the node and add the resulting nodes to the search tree
```

Tree search


Arad
Sibiu
Timisoara
Zerind
Arad
Fagaras
Oradea
Rimnicu Vilcea
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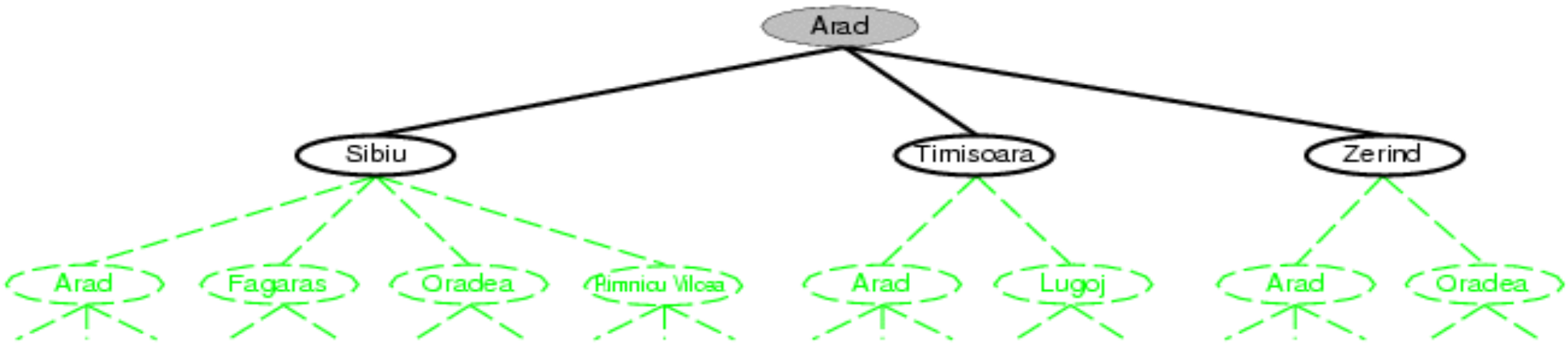
Lugoj
Arad
Oradea

Tree search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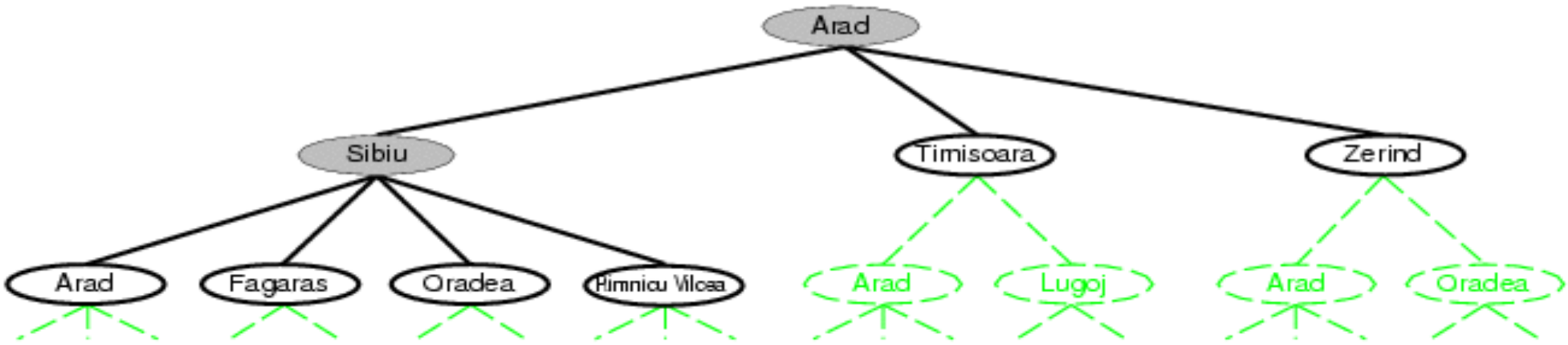
Tree search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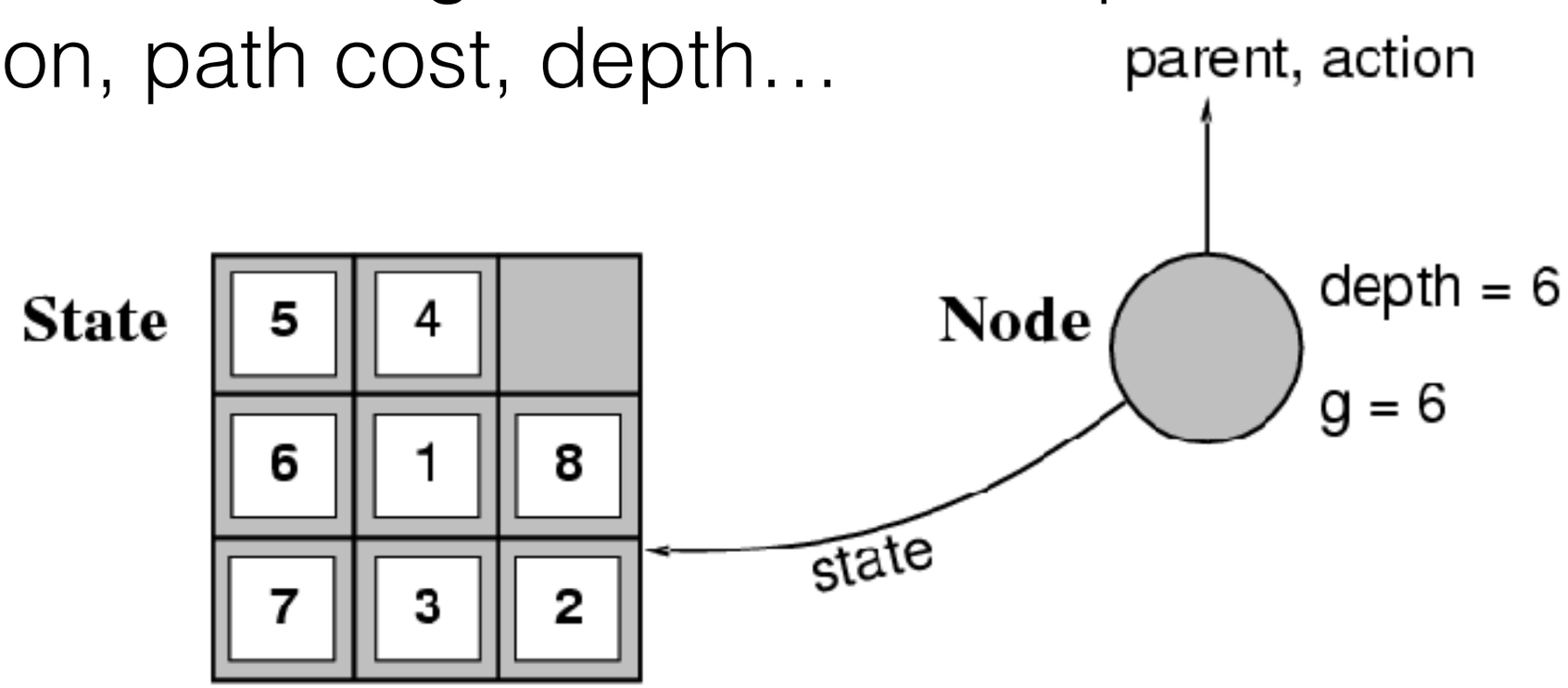
```
function TREE-SEARCH( problem, fringe) returns a solution, or failure
    fringe ← INSERT(MAKE-NODE(INITIAL-STATE[problem]), fringe)
    loop do
        if fringe is empty then return failure
        node ← REMOVE-FRONT(fringe)
        if GOAL-TEST[problem](STATE[node]) then return SOLUTION(node)
        fringe ← INSERTALL(EXPAND(node, problem), fringe)

---

function EXPAND( node, problem) returns a set of nodes
    successors ← the empty set
    for each action, result in SUCCESSOR-FN[problem](STATE[node]) do
        s ← a new NODE
        PARENT-NODE[s] ← node;  ACTION[s] ← action;  STATE[s] ← result
        PATH-COST[s] ← PATH-COST[node] + STEP-COST(node, action, s)
        DEPTH[s] ← DEPTH[node] + 1
        add s to successors
    return successors
```

Nodes versus states

- A state is a configuration of an environment/agent
- A node is a data structure constituting part of a search tree, might include state, parent node, action, path cost, depth…

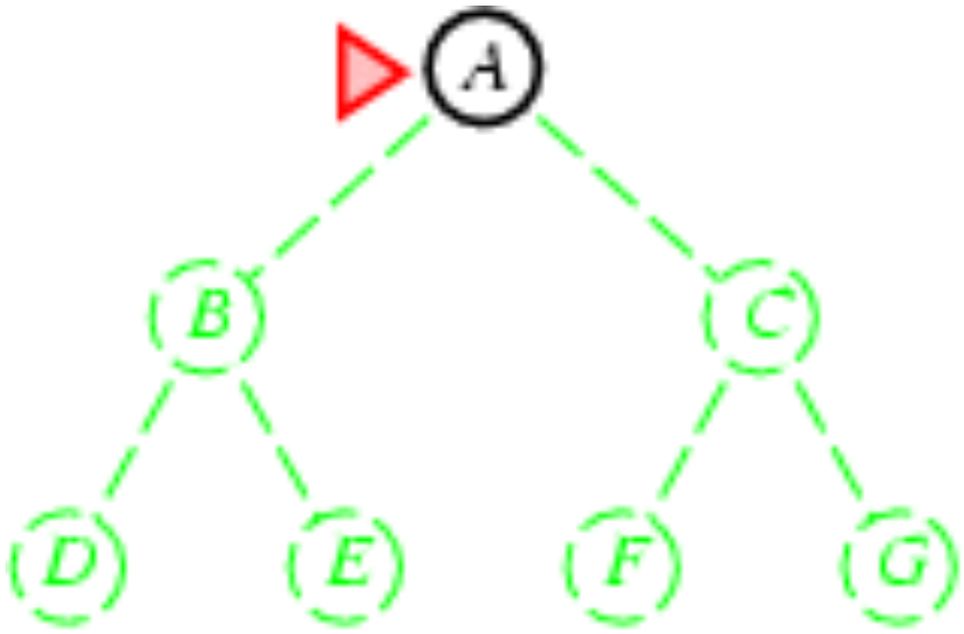


Uninformed search

- Uninformed search strategies use only the information available in the problem definition
- Breadth-first search
- Uniform cost search
- Depth-first search
- Depth-limited search
- Iterative deepening search

Breadth-first search

- Expand shallowest unexpanded node
- Implementation: new nodes added to a FIFO queue



Breadth-first search

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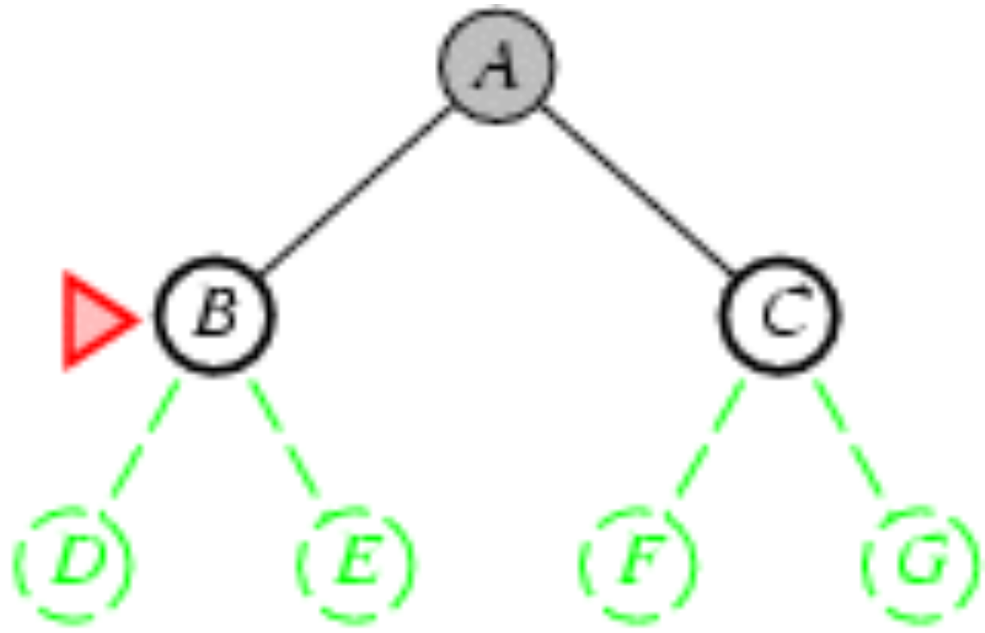

Breadth-first search

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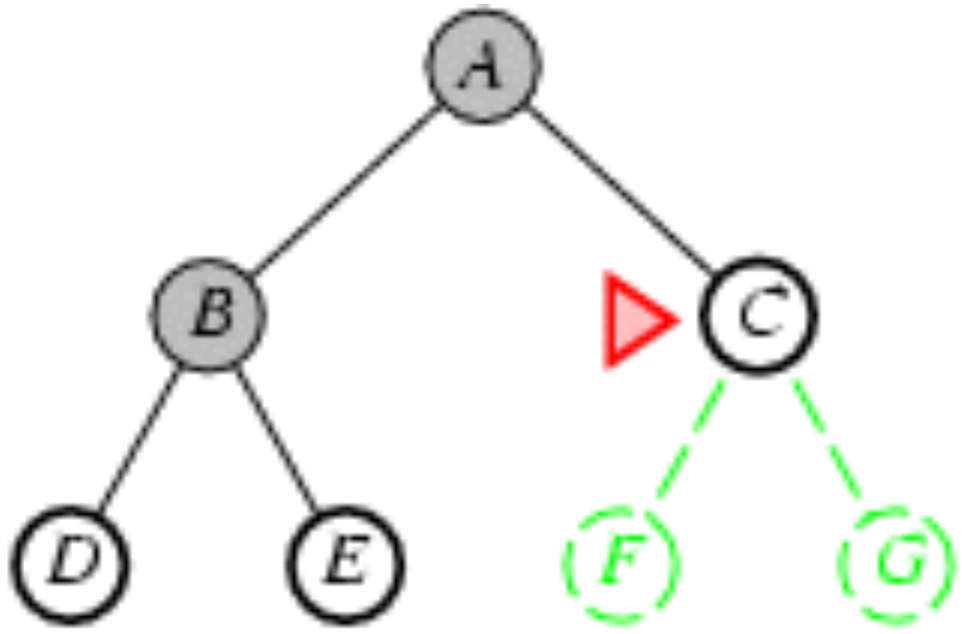

Breadth-first search

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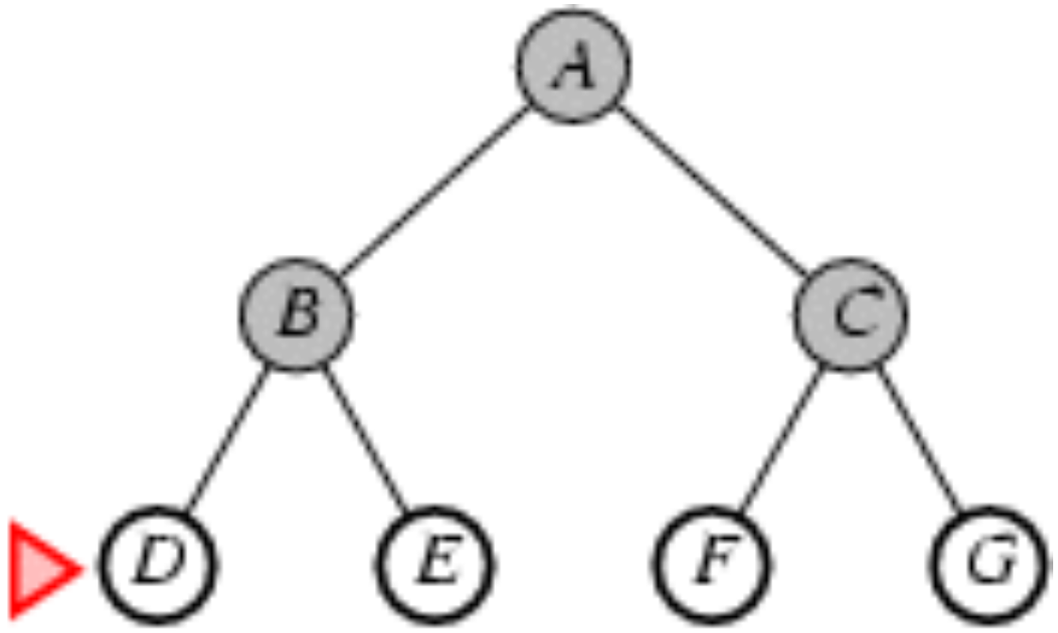
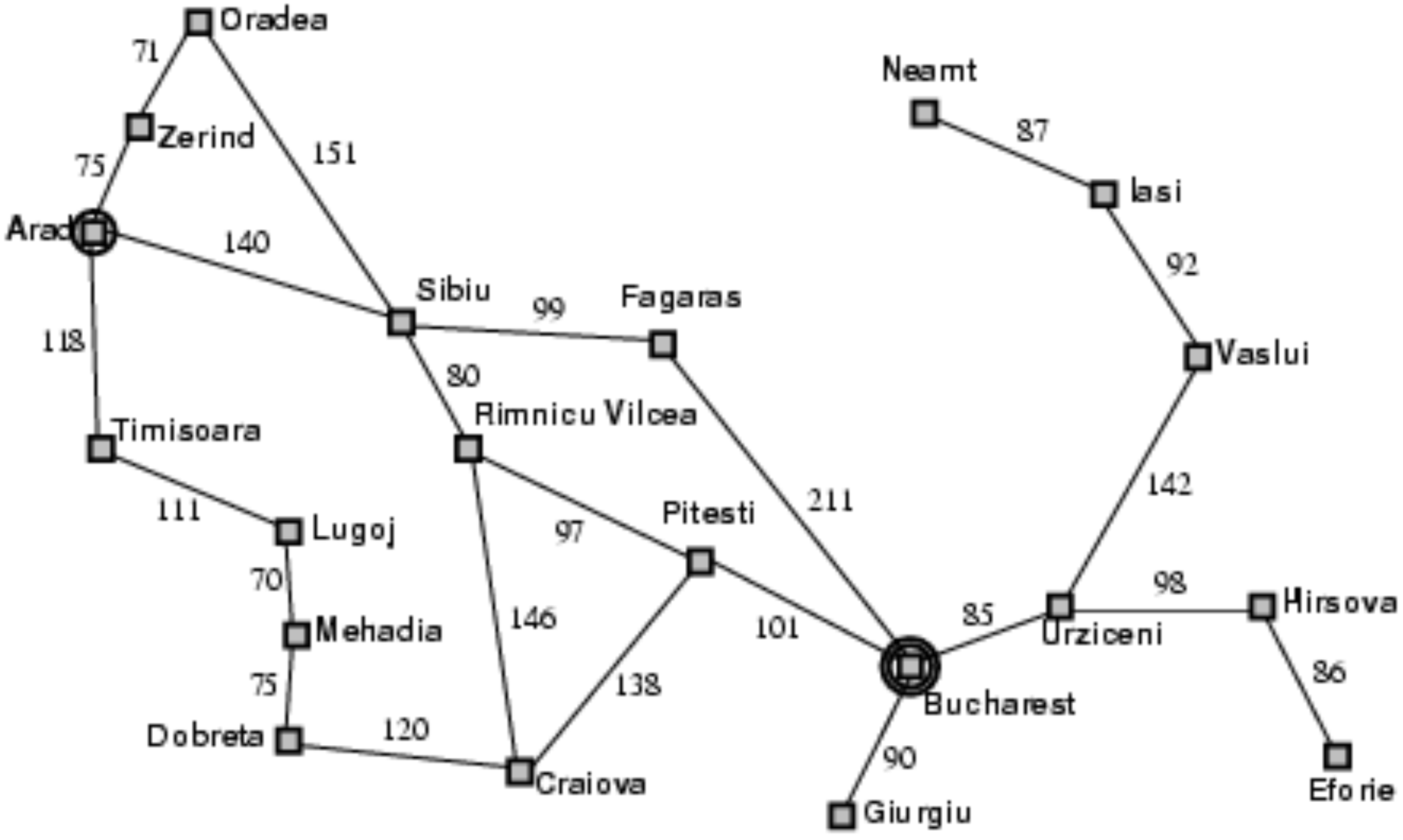


Breadth-first search

- Complete? Yes (if b is finite)
- Time? $1+b+b^2+b^3+\ldots +b^d + b(b^d-1) = O(b^{d+1})$
- Space? $O(b^d+1)$ (keeps every node in memory)
- Optimal? Yes (if cost = 1 per step)

From Arad to Bucharest



Uniform-cost search

- Expand least-cost unexpanded node
- Equivalent to breadth-first if step costs all equal
- Complete and optimal