Heuristic (or Informed) Search Methodologies

Lecture 8: Artificial Intelligence

Dr. Bonaventure Chidube Molokwu

bonaventure.molokwu[at]csus.edu

College of Engineering and Computer Science
California State University
Sacramento
California - United States of America

Heuristic or Informed Search

Lecture/Week Outline & Learning Outcomes

1. **Lesson/Week Outline:**
   - 1.1 Heuristic (or Informed) Search

2. **Learning Outcomes:**
   - 2.1 Heuristic function for cost estimation.
   - 2.2 Conceptual details of Heuristic/Informed Search algorithms: Best-First Search (Greedy Search, A* Search, IterativeDeepening A* Search).
   - 2.3 Real-world usage scenarios such as pathfinding, decision-making process, planning, etc.

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Best-First Search: A-Star Search
Best-First Search: IDA* Search
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Heuristic or Informed Search
Introduction

- **search(Heuristic or Informed):**
  - AI: +knowledge(Heuristics) *execute* operation(Search)
  - technique(AI) that employs add-on knowledge/heuristics (or additional logic) wrt. executing operation(Search).
  - Based on function(Evaluation, $f(n)$) which MUST employ function(Heuristic, $h(n)$) wrt. estimating(Cost) from $\exists$ node(Source) to node(Destination).

- **Examples of search(Heuristic or Informed) algorithms:**
  - Best-First Search (Greedy Search, A* Search, IterativeDeepening A* Search)

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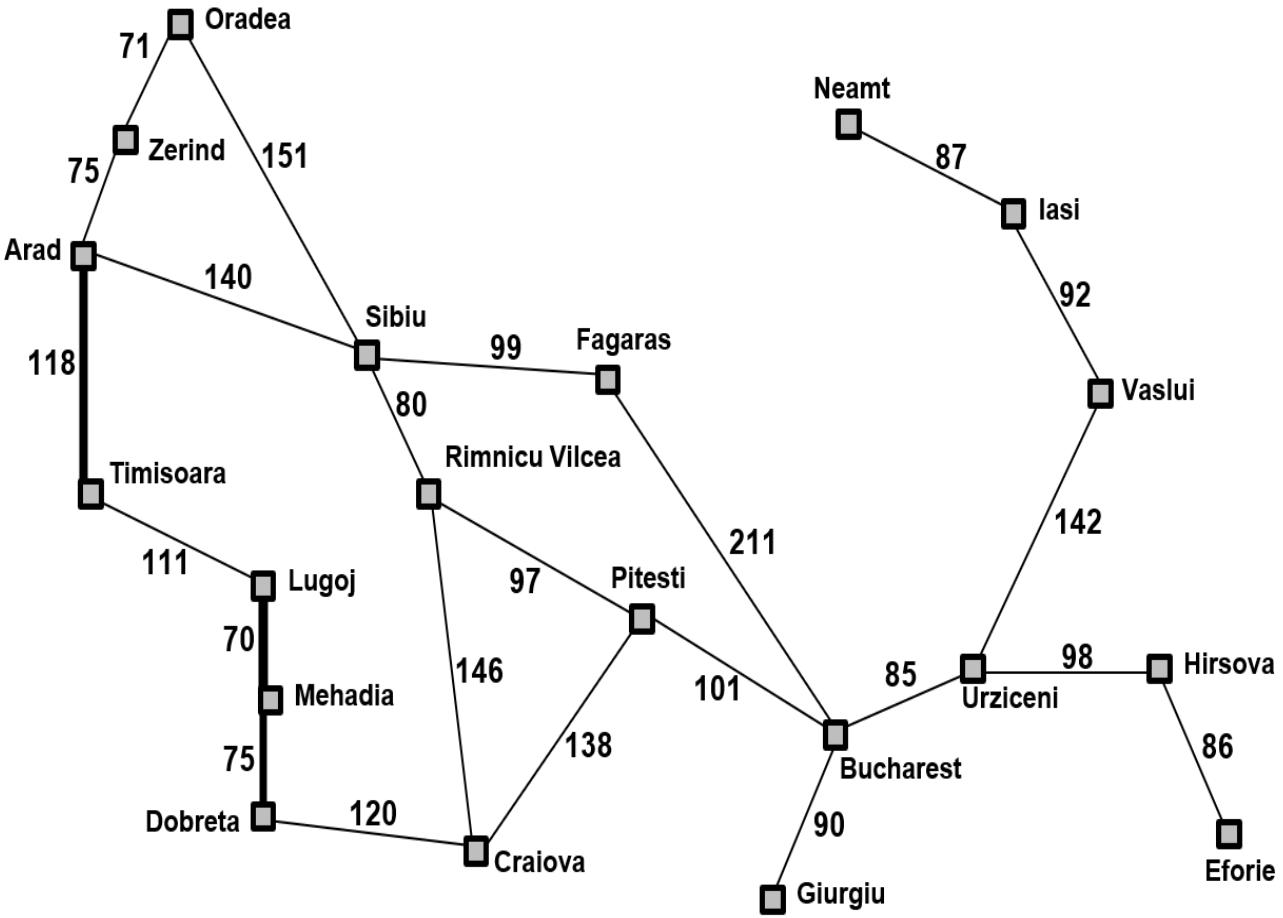
Best-First Search: Greedy Search



Straight-line distance to: Bucharest	
Arad	366
Bucharest	0
Craiova	160
Dobreta	242
Eforie	161
Fagaras	178
Giurgiu	77
Hirsova	151
Iasi	226
Lugoj	244
Mehadia	241
Neamt	234
Oradea	380
Pitesti	98
Rimnicu Vilcea	193
Sibiu	253
Timisoara	329
Urziceni	80
Vaslui	199
Zerind	374

- **Best-First Search(Greedy Search):**
  - function(Evaluation, $f(n)$) == function(Heuristic, $h(n)$) = straight-line distance from node(n) to node(Bucharest).

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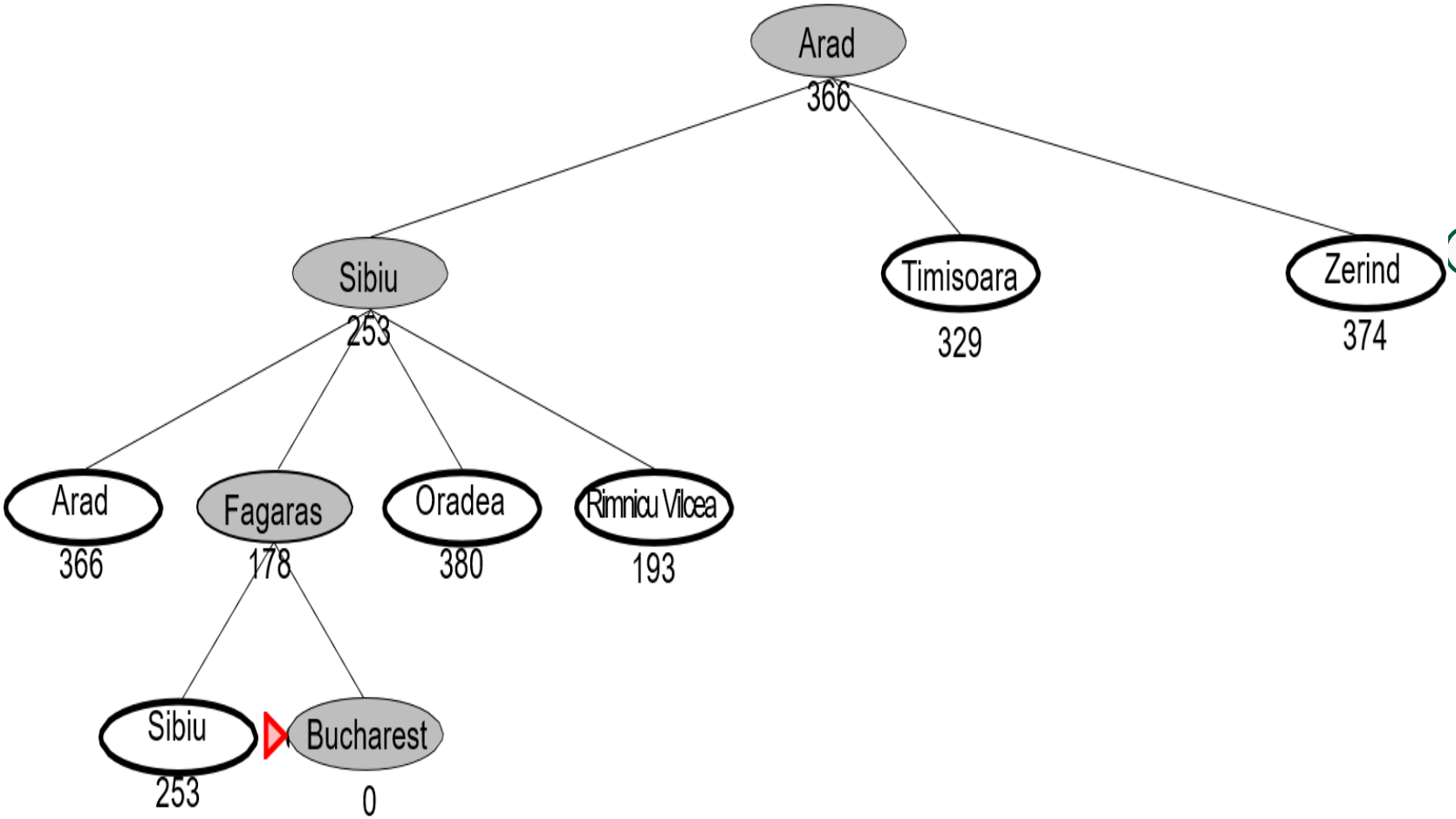
Best-First Search: Greedy Search



- **Best-First Search(Greedy Search):**
  - During traversal, it expands/drills into the node which is closest to the goal (herein we used `minimal` cost) until node(Goal/Destination) is reached.

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Best-First Search: Properties/Characteristics of Greedy Search

- **property(Optimality):**
  - Does NOT always yield the solution/path(Optimal) because it's solely based on function(Evaluation, $f(n)$) == function(Heuristic, $h(n)$).
  - With the aid of function(Evaluation/Heuristic), the path(Optimal) = `Arad, Sibiu, Fagaras, Bucharest` = 140 + 99 + 211 = 450
  - However, consider a path(Shorter) = `Arad, Sibiu, Rimnicu Vilcea, Pitesti, Bucharest` = 140 + 80 + 97 + 101 = 418

- **property(Run-time Complexity):**
  - $O(b^m)$: where b = Branching factor (average number of children per node) AND m = Depth of the deepest node (maximum depth of the search tree).

- **property(Space Complexity):**
  - $O(b^m)$: It stores all the nodes in memory, and b = Branching factor (average number of children per node) AND m = Depth of the deepest node (maximum depth of the search tree).

- **property(Other):**
  - Can lead to multiple visits (repeated-state checking) wrt. a node. Thus, can get stuck in loops.

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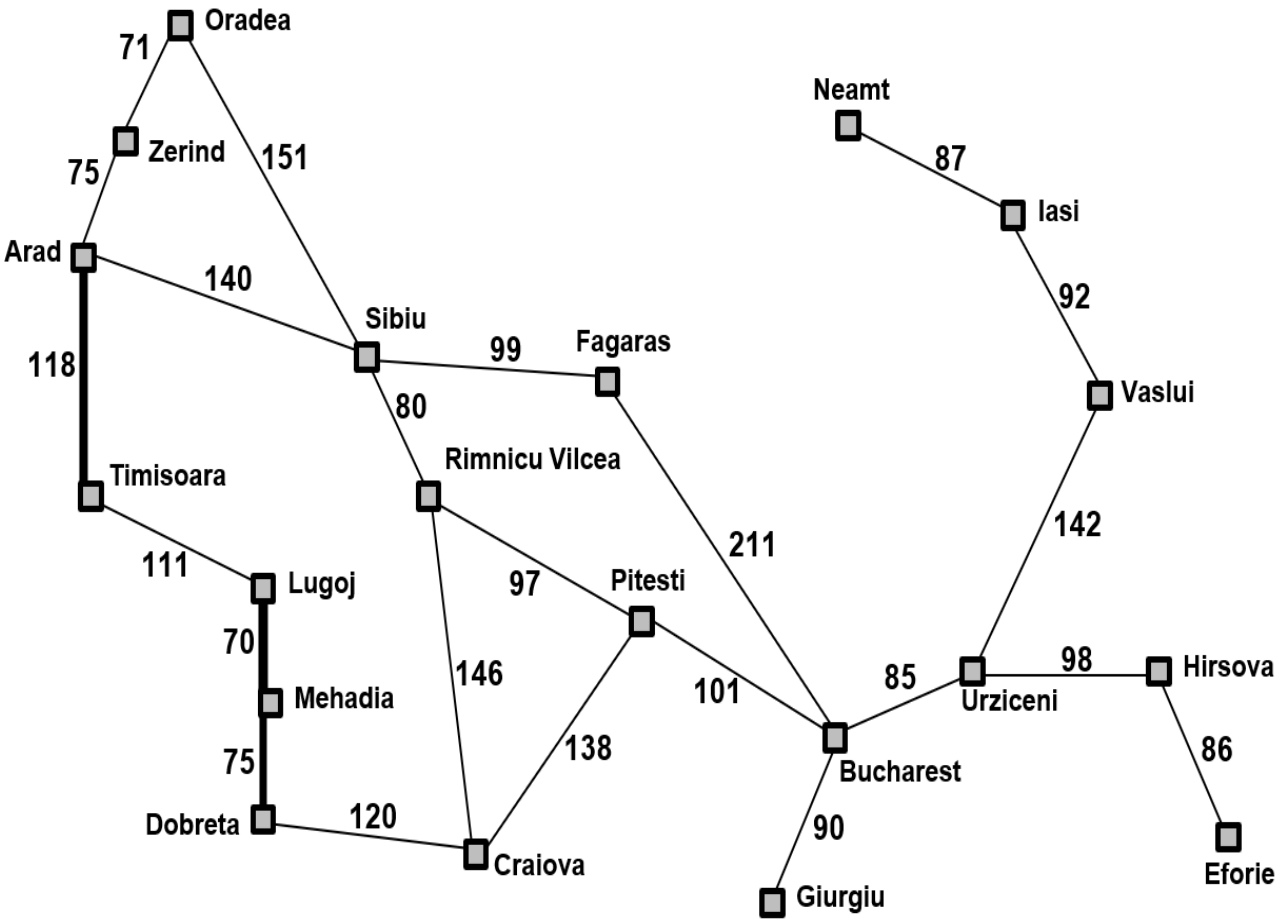
Best-First Search: Greedy Search



Straight-line distance to: Urziceni	
Arad	366
Bucharest	80
Craiova	160
Dobreta	242
Eforie	161
Fagaras	178
Giurgiu	77
Hirsova	151
Iasi	226
Lugoj	244
Mehadia	241
Neamt	234
Oradea	380
Pitesti	98
Rimnicu Vilcea	193
Sibiu	253
Timisoara	329
Urziceni	0
Vaslui	199
Zerind	374

- **Best-First Search(Greedy Search):**
  - function(Evaluation, $f(n)$) == function(Heuristic, $h(n)$) = straight-line distance from node(n) to node(Urziceni).

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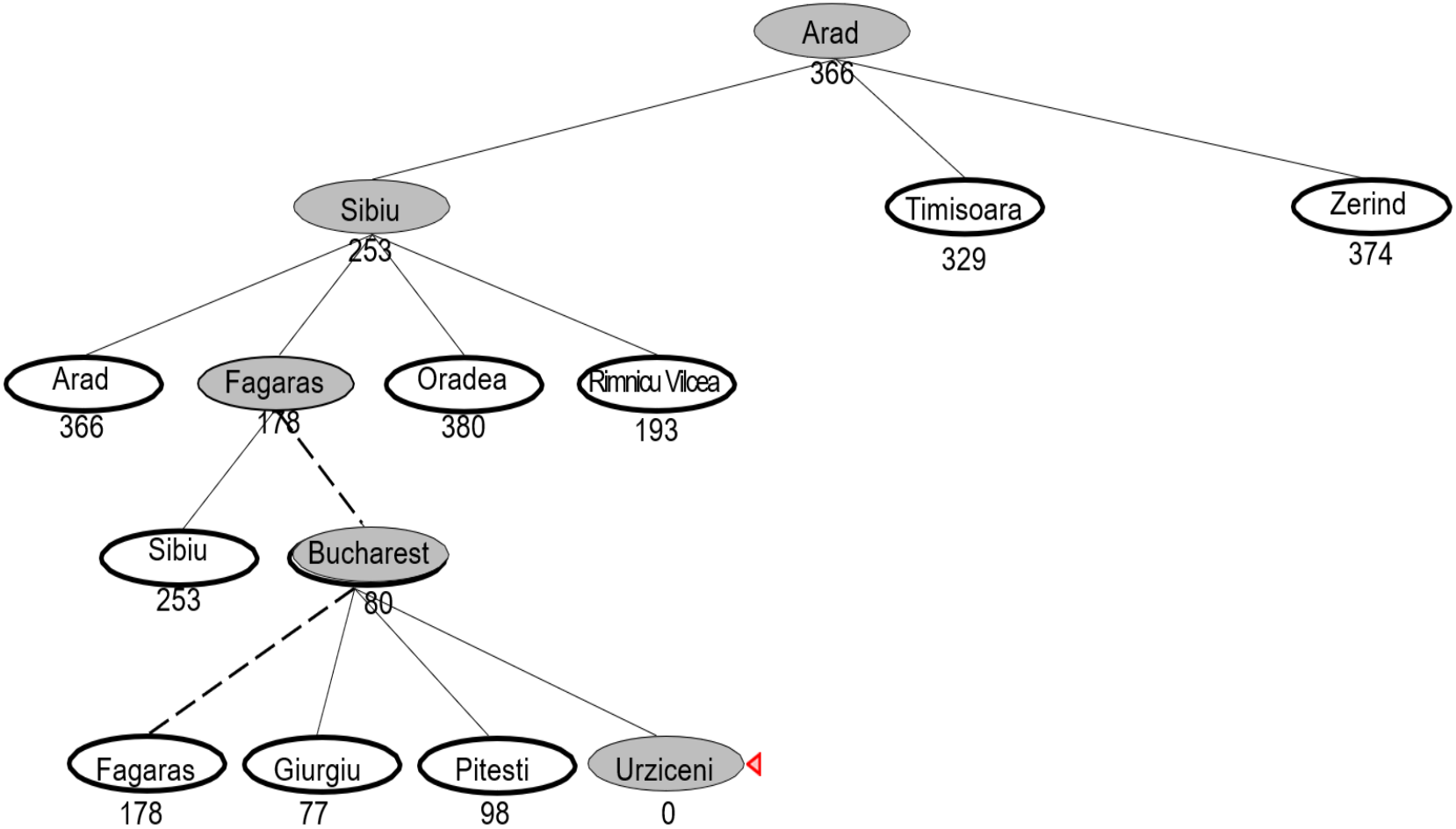
Best-First Search: Greedy Search



- **property(Other) - Best-First Search(Greedy Search):**
  - Can lead to multiple visits (repeated-state checking) wrt. a node. Thus, can get stuck in loops.
  - NOTE: `Fagaras` had visits(Multiple) = 2, before reaching node(Urziceni).

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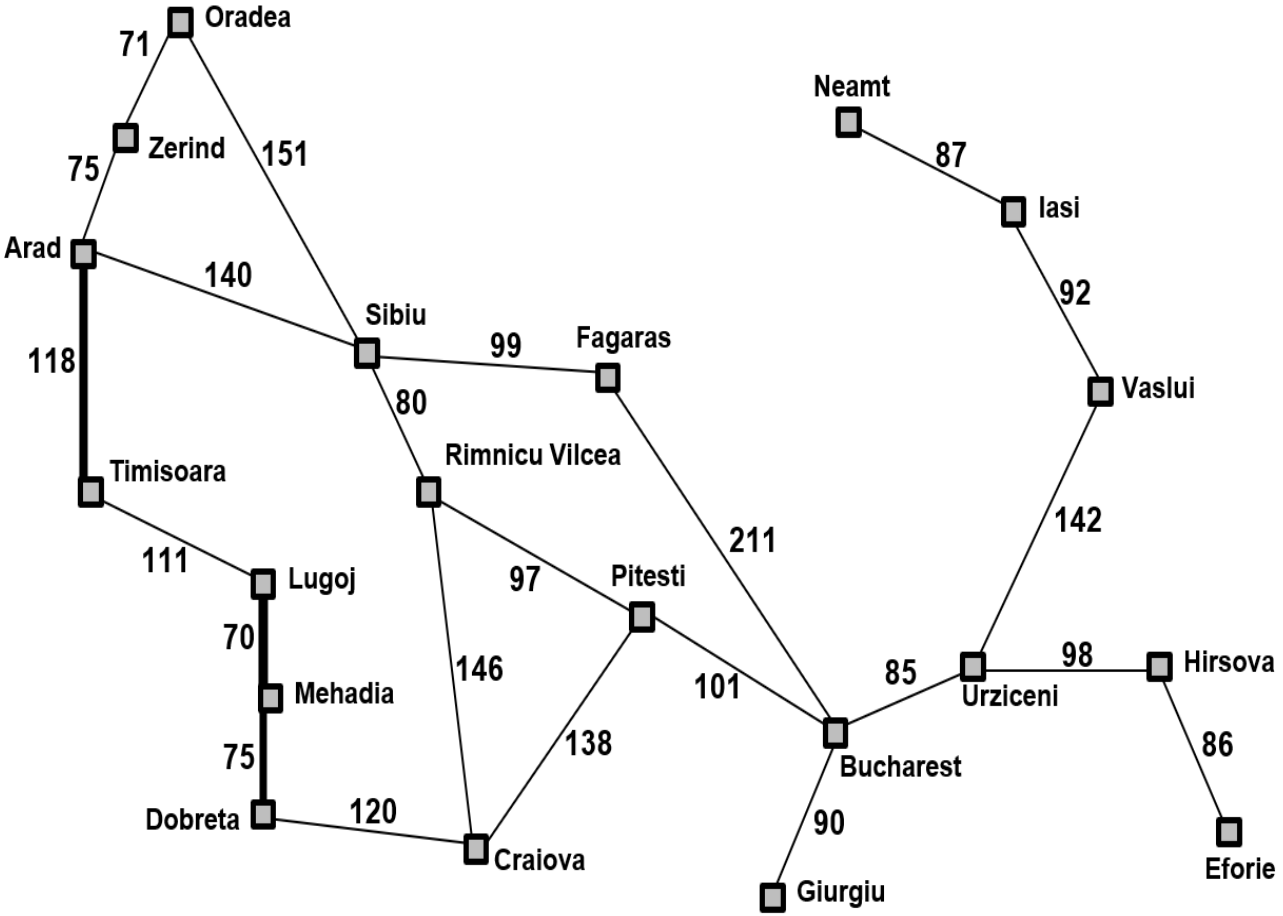
Best-First Search: A* (A-Star) Search



Straight-line distance to: Bucharest	
Arad	366
Bucharest	0
Craiova	160
Dobreta	242
Eforie	161
Fagaras	178
Giurgiu	77
Hirsova	151
Iasi	226
Lugoj	244
Mehadia	241
Neamt	234
Oradea	380
Pitesti	98
Rimnicu Vilcea	193
Sibiu	253
Timisoara	329
Urziceni	80
Vaslui	199
Zerind	374

- **Best-First Search(A* Search):**
  - function(Evaluation, $f(n)$) = ShortestPath, $g(n)$ + Heuristic, $h(n)$
  - function(Evaluation, $f(n)$) = function(Dijkstra's) + function(Heuristic)

    Heuristic, $h(n)$ = straight-line distance from node(n) to node(Bucharest)

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Best-First Search: A* (A-Star) Search

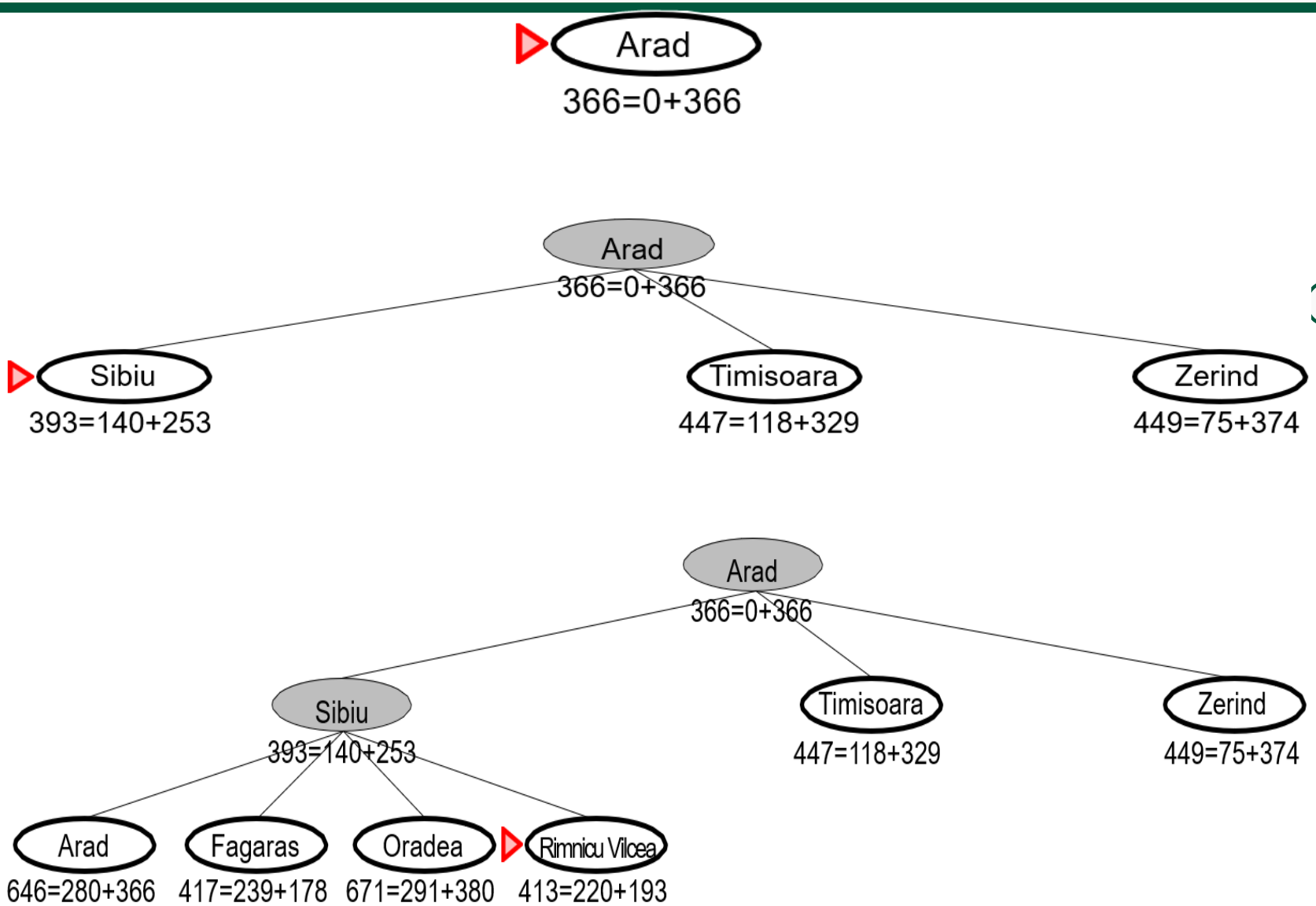

Figure: Evaluation function, $f(n)$ = ShortestPath, $g(n)$ + Heuristic, $h(n)$

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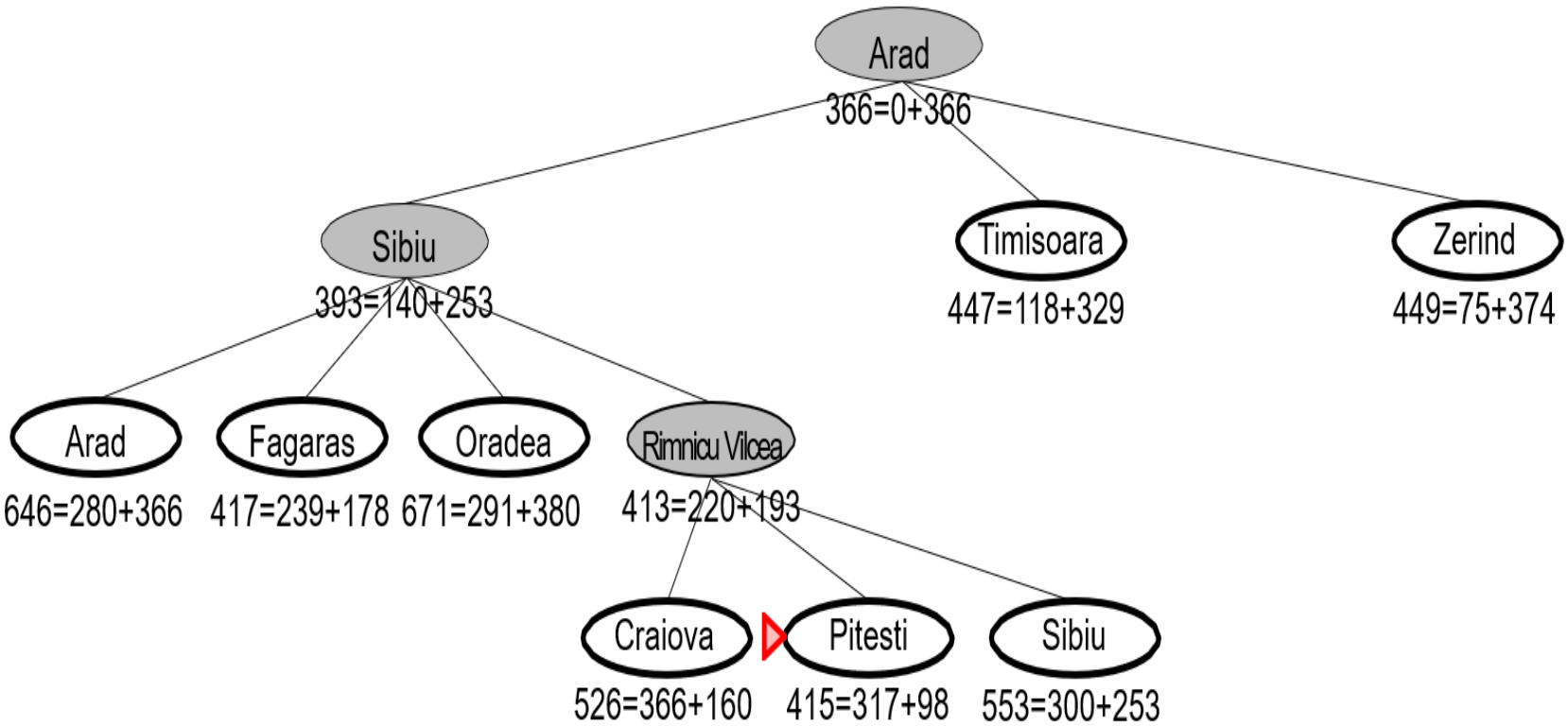
Best-First Search: A* (A-Star) Search



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Best-First Search: A* (A-Star) Search

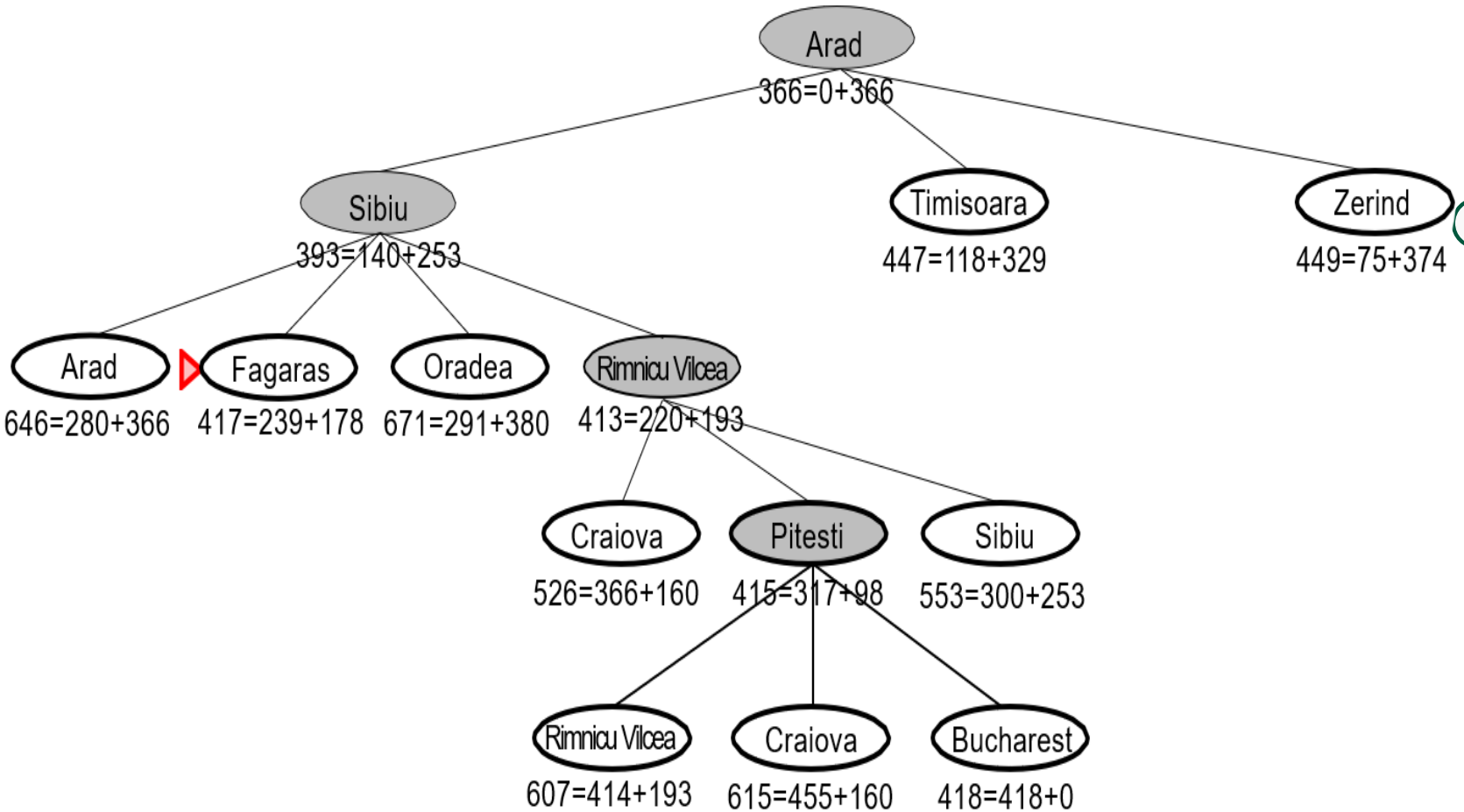

Figure: Evaluation function, $f(n)$ = ShortestPath, $g(n)$ + Heuristic, $h(n)$

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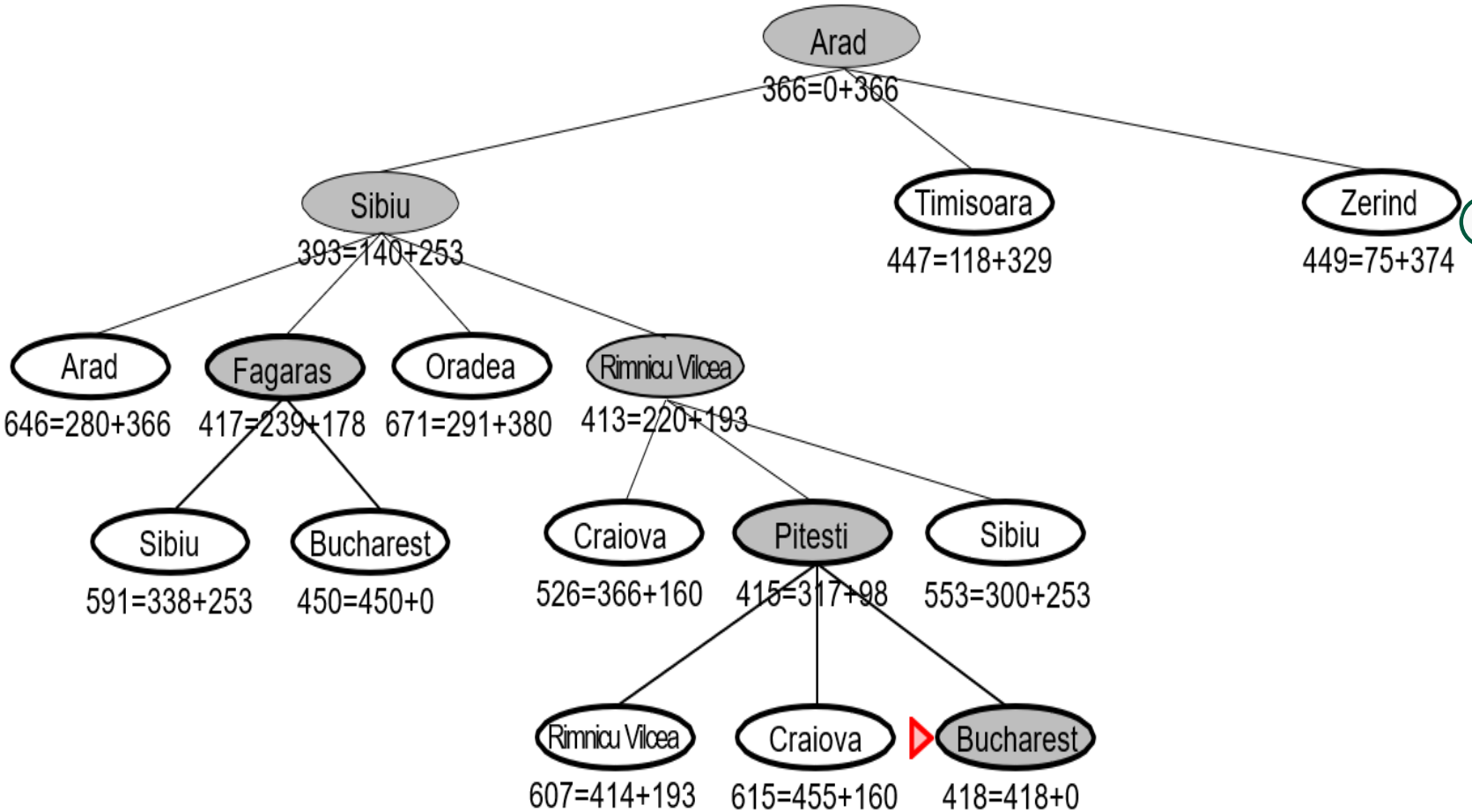
Best-First Search: A* (A-Star) Search



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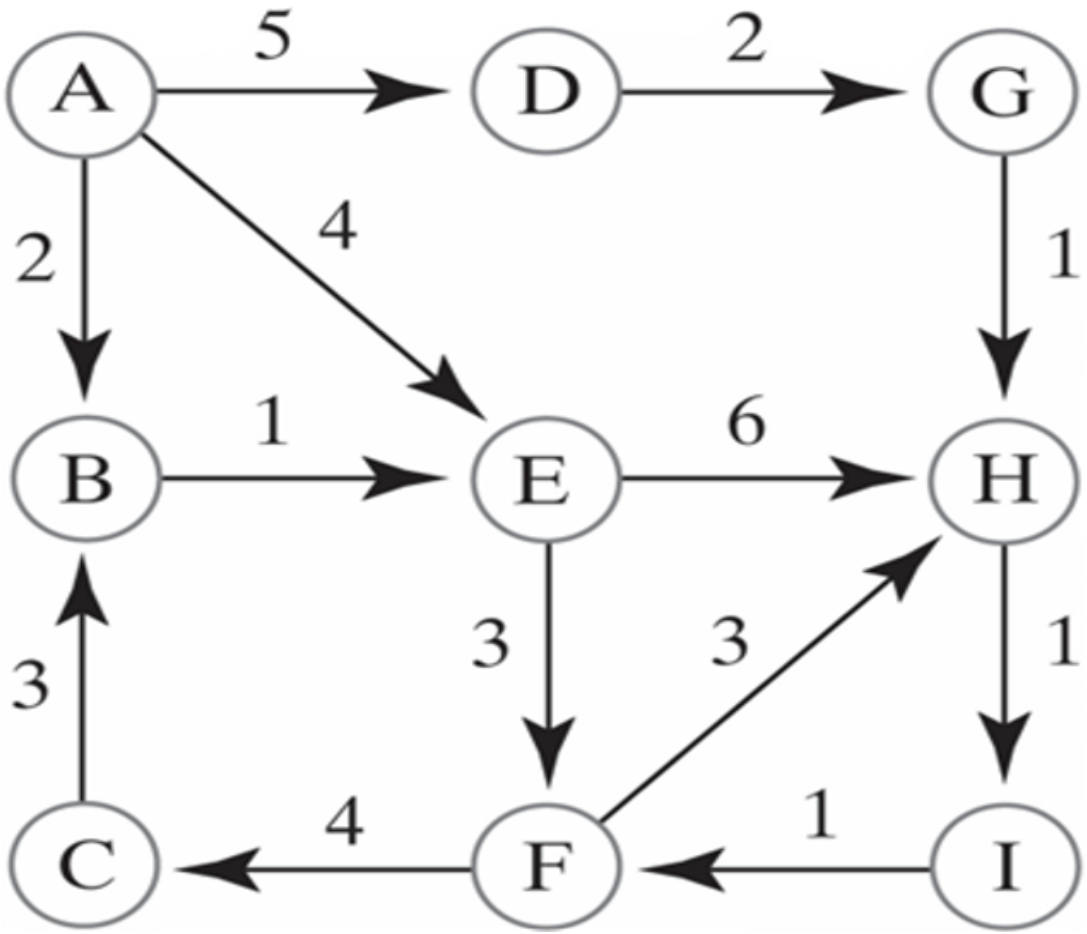
Best-First Search: A* (A-Star) Search



Heuristic cost to goal: **I**

A	10
B	8
C	5
D	7
E	4
F	3
G	5
H	2
I	0

- **Best-First Search(A* Search):**
  - function(Evaluation, $f(n)$) = ShortestPath, $g(n)$ + Heuristic, $h(n)$
  - function(Evaluation, $f(n)$) = function(Dijkstra's) + function(Heuristic)

    Heuristic, $h(n)$ = straight-line distance from node(n) to node(I)

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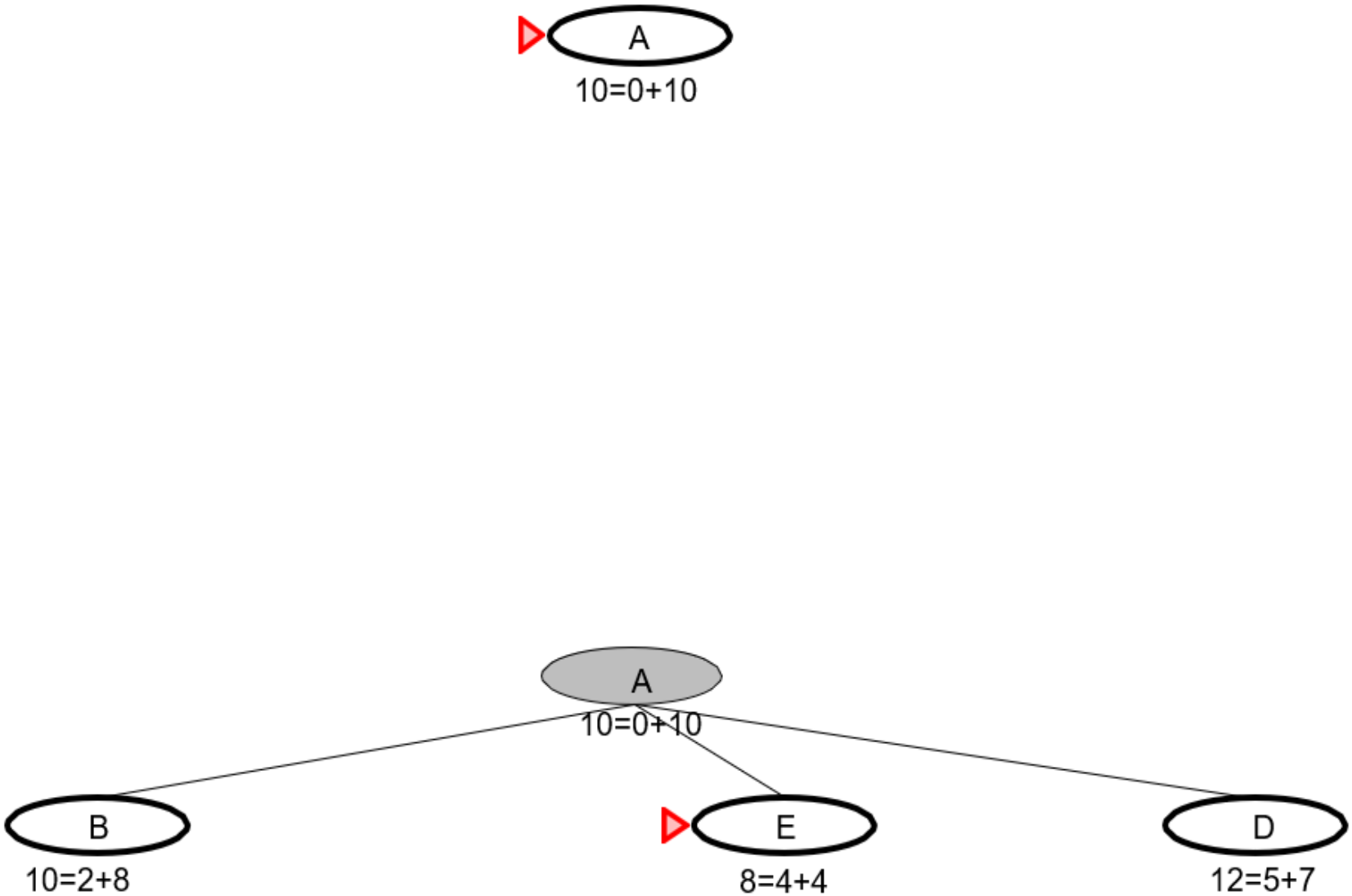
Best-First Search: A* (A-Star) Search



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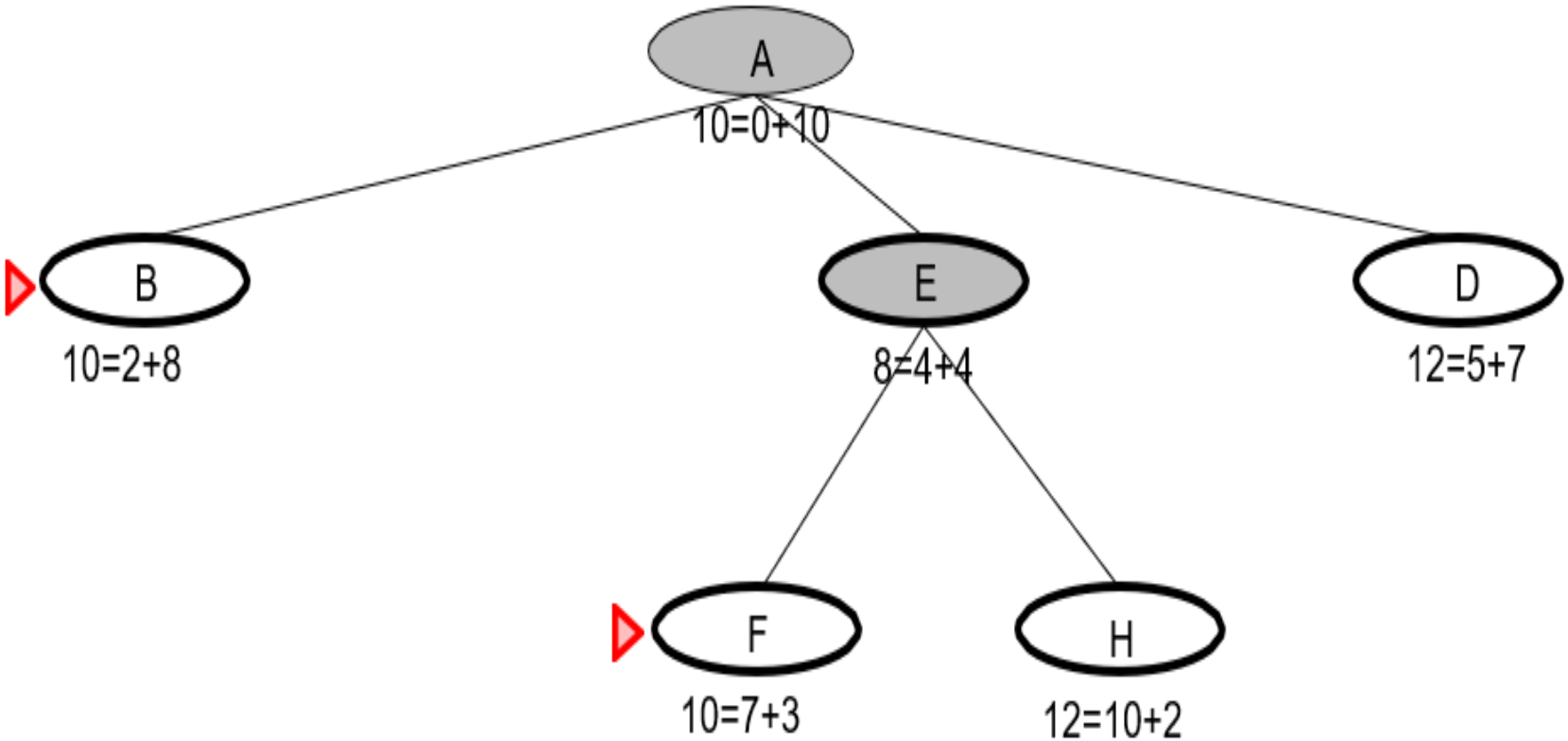
Best-First Search: A* (A-Star) Search



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Best-First Search: A* (A-Star) Search

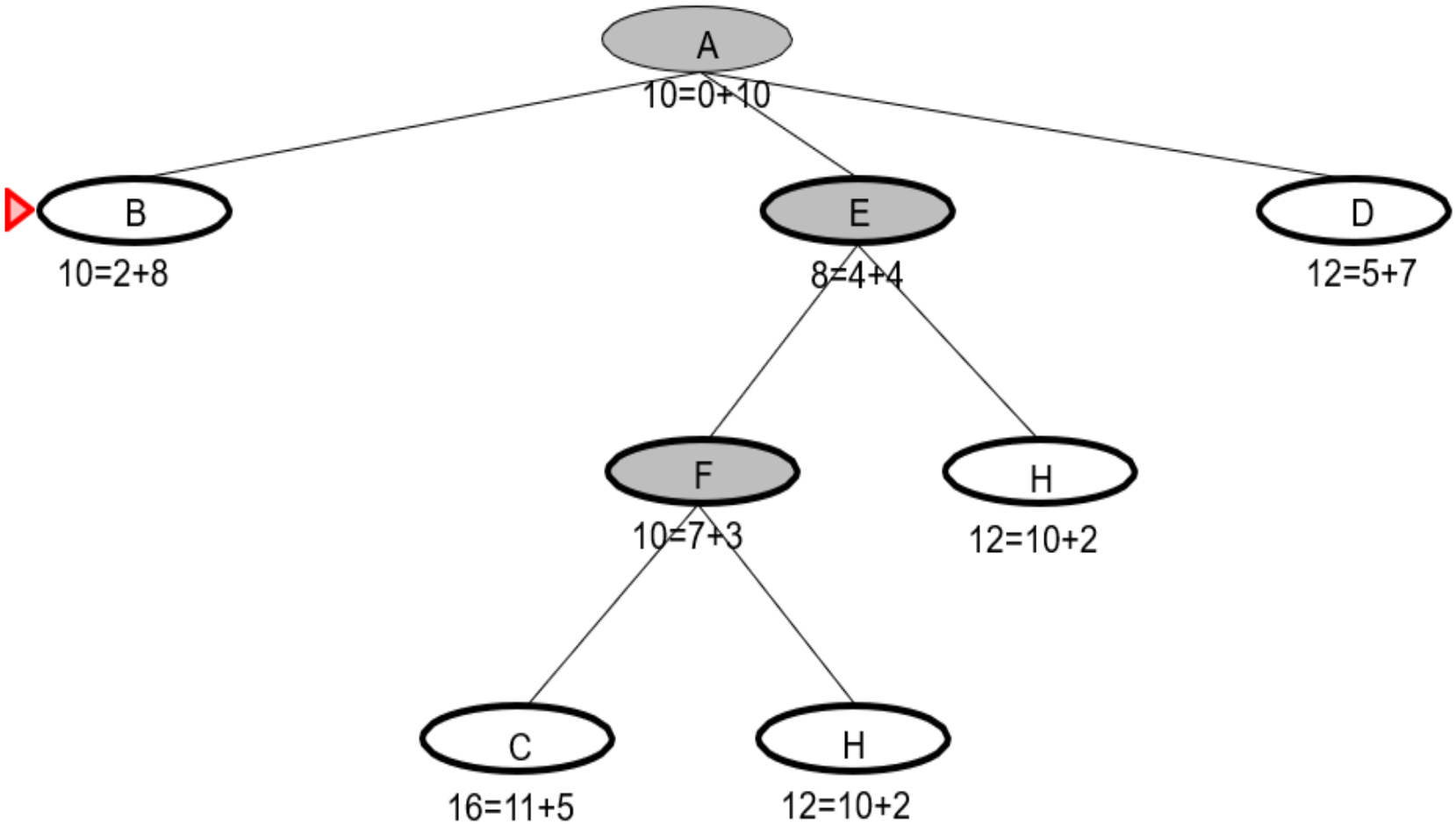

Figure: Evaluation function, $f(n)$ = ShortestPath, $g(n)$ + Heuristic, $h(n)$

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Best-First Search: A* (A-Star) Search

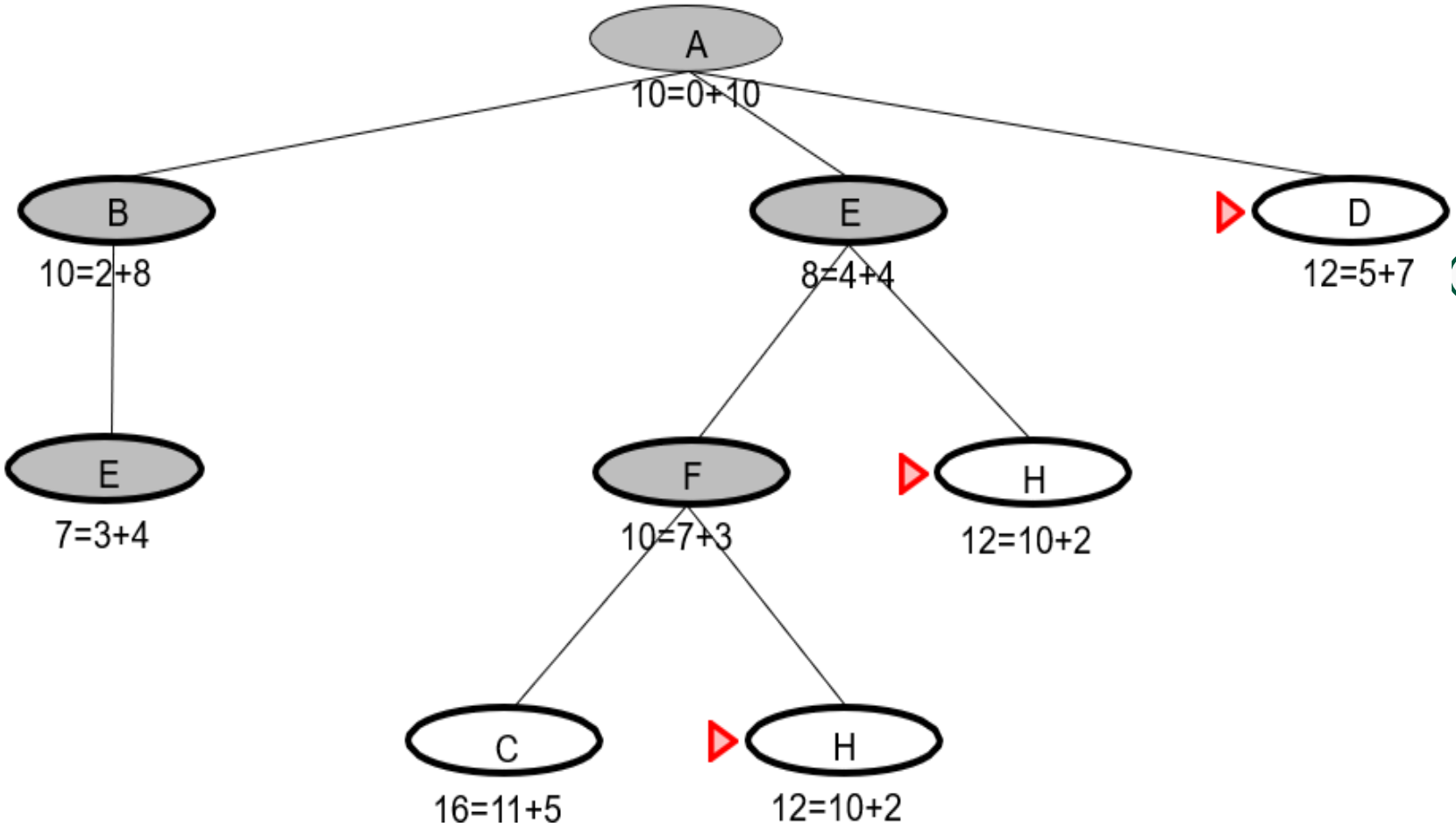

Figure: Evaluation function, $f(n)$ = ShortestPath, $g(n)$ + Heuristic, $h(n)$

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Best-First Search: A* (A-Star) Search

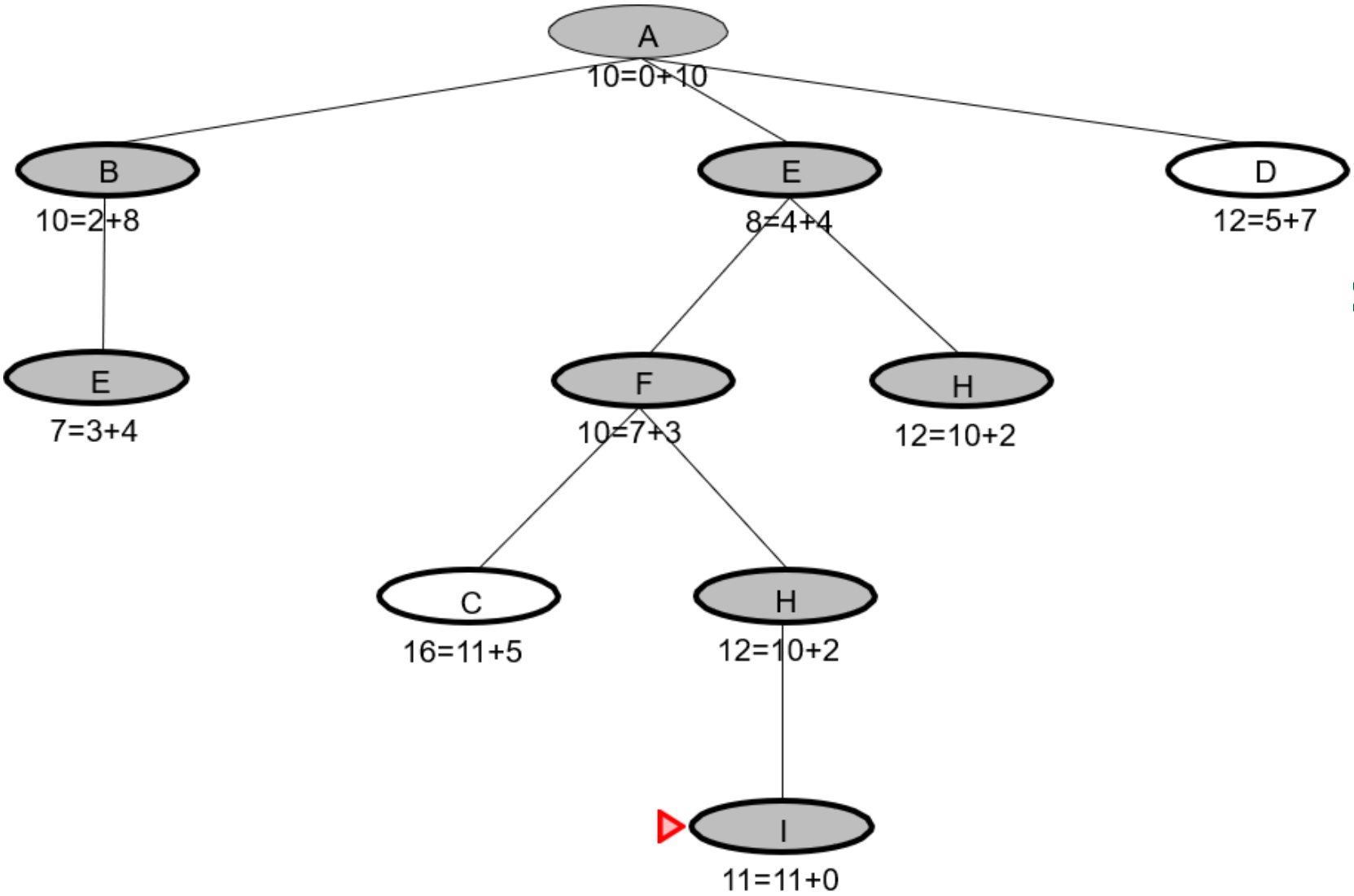

Figure: Evaluation function, $f(n)$ = ShortestPath, $g(n)$ + Heuristic, $h(n)$

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Best-First Search: A* (A-Star) Search

- **property(Optimality):**
  - Does yield the solution/path(Optimal).
- **property(Run-time Complexity):**
  - $O(b^d)$: where b = Branching factor (average number of children per node) AND d = Depth of the optimal solution.
- **property(Space Complexity):**
  - $O(b^d)$: It stores all the nodes in memory, and b = Branching factor (average number of children per node) AND d = Depth of the optimal solution.
- **property(Other):**
  - Always finds a solution provided there is NOT `infinitely` many nodes, AND that a solution does exists wrt. graph.

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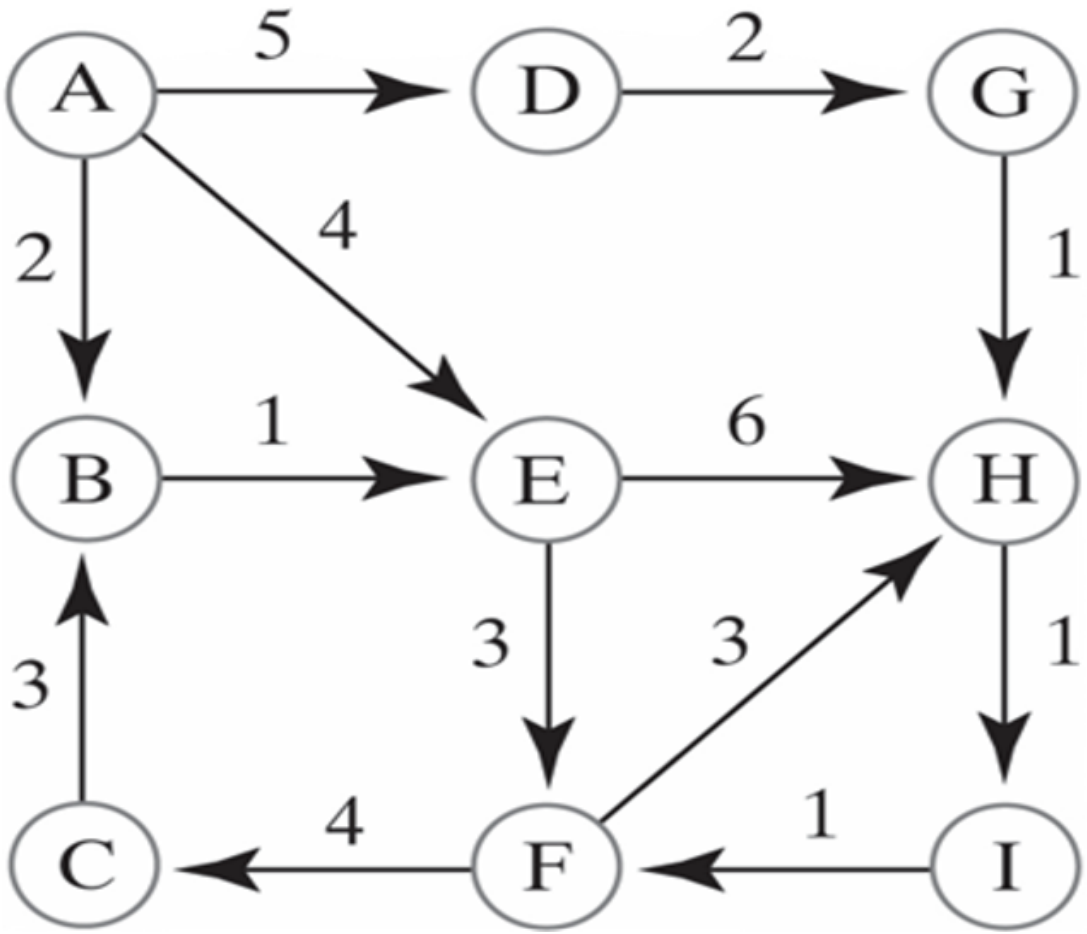
Best-First Search: Iterative Deepening A* Search



Heuristic cost to goal: **I**

A	10
B	8
C	5
D	7
E	4
F	3
G	5
H	2
I	0

- **Best-First Search(Iterative Deepening A* Search):**
  - function(Evaluation, $f(n)$) = LeftmostPath, $g(n)$ + Heuristic, $h(n)$
  - function(Evaluation, $f(n)$) = search(DepthFirst) + search(A*)

    Heuristic, $h(n)$ = straight-line distance from node(n) to node(I)

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Best-First Search: Iterative Deepening A* Search

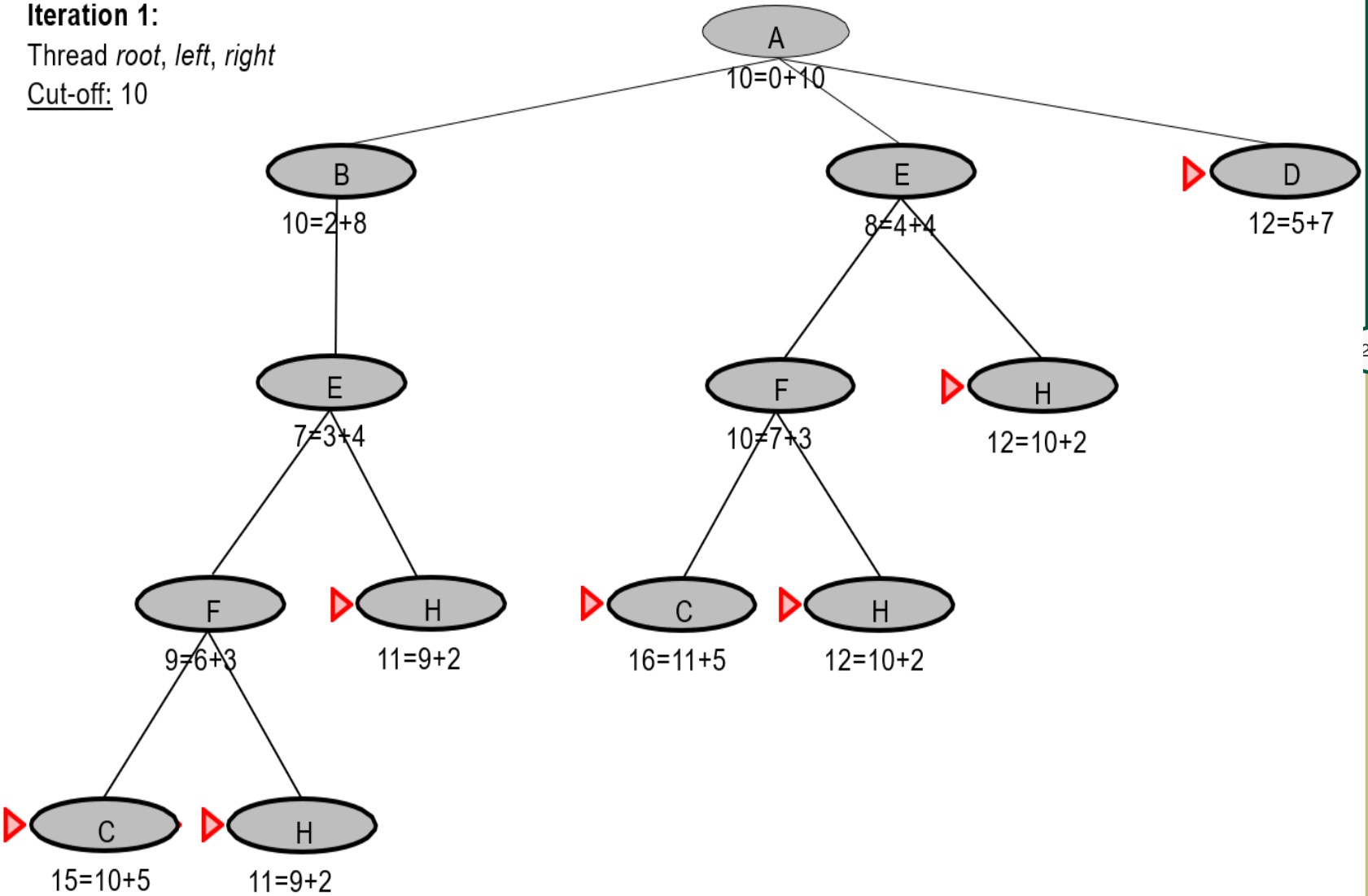

Figure: Evaluation function, $f(n)$ = LeftmostPath, $g(n)$ + Heuristic, $h(n)$

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Best-First Search: Iterative Deepening A* Search

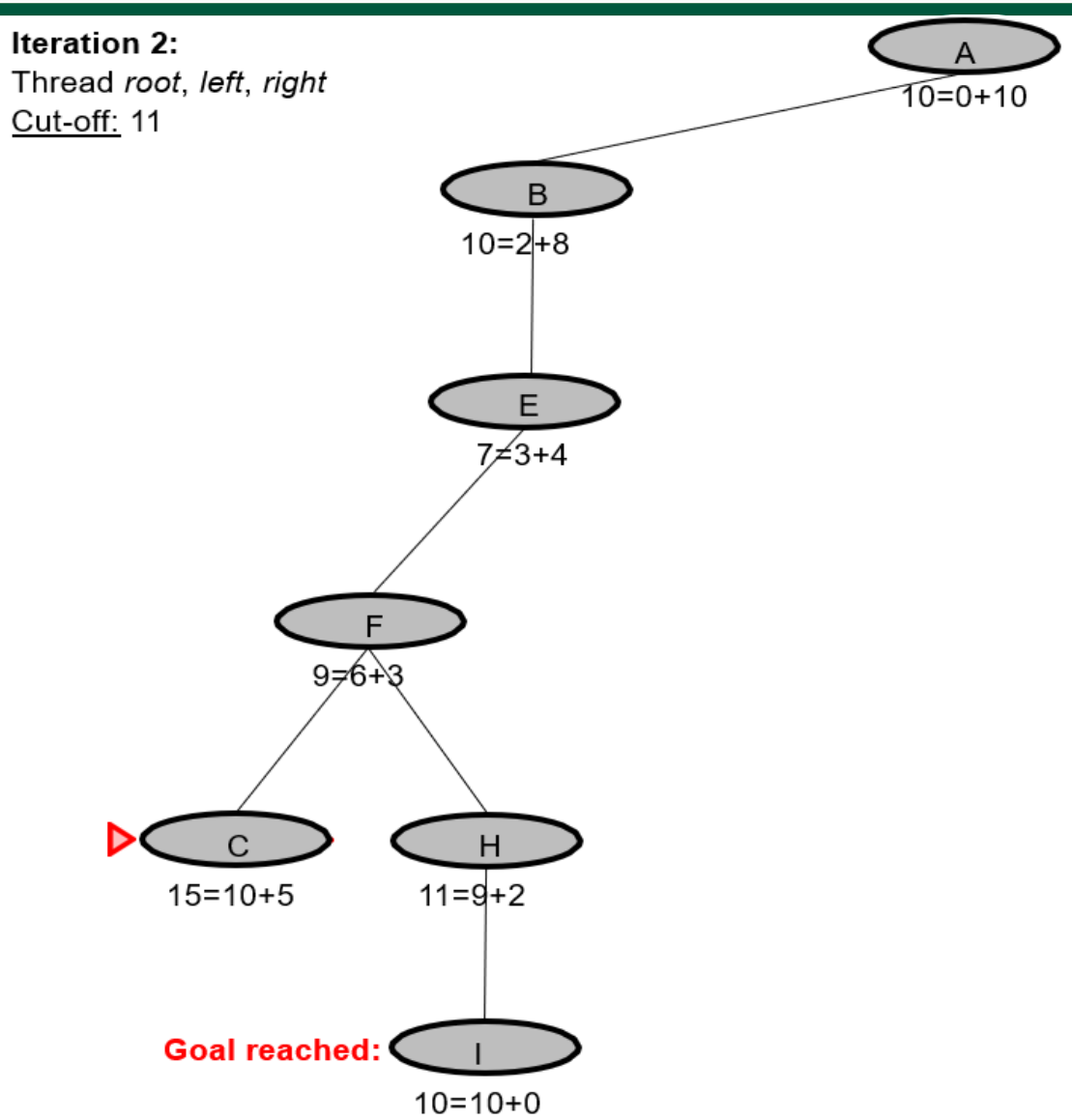

Figure: Evaluation function, $f(n)$ = LeftmostPath, $g(n)$ + Heuristic, $h(n)$

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Best-First Search: Iterative Deepening A* Search

- **property(Optimality):**
  - Does yield the solution/path(Optimal).
- **property(Run-time Complexity):**
  - $O(b^d)$: where b = Branching factor (average number of children per node) AND d = Depth of the optimal solution.
- **property(Space Complexity):**
  - $O(d)$: It stores ONLY processed nodes in memory, and d = Depth of the optimal solution.
- **property(Other):**
  - Always finds a solution provided that a solution does exists wrt. graph. It is ideal for graphs with `MANY` nodes.

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1. **A strategy(Search) which does not employ any *Rule of Inference* towards searching and/or reaching its goal is referred to as?**
   A. Blind Search
   B. Heuristic Search
   C. Constraint Satisfaction Search
   D. None of the above

2. **A strategy(Search) which does employ a function(Evaluation) towards searching and/or reaching its goal is referred to as?**
   A. Blind Search
   B. Heuristic Search
   C. Constraint Satisfaction Search
   D. None of the above

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3. **A strategy(Search) which solely depends on the light of the function(Evaluation) towards searching and/or reaching its goal is referred to as?**
   A. A* (Best-First) Search
   B. Iterative Deepening A* (Best-First) Search
   C. Greedy (Best-First) Search
   D. None of the above

4. **A strategy(Search) which combines function(Evaluation) and the path(Shortest) strength towards searching and/or reaching a goal is referred to as?**
   A. Breath First Search
   B. Greedy (Best-First) Search
   C. A* (Best-First) Search
   D. None of the above

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5. **A strategy(Search) which combines the strength of search(DepthFirst), the strength of path(Shortest) to a goal, and function(Evaluation) with respect to searching and/or reaching a goal is referred to as?**
   A. A* (Best-First) Search
   B. Iterative Deepening A* (Best-First) Search
   C. Greedy (Best-First) Search
   D. None of the above

6. **Which of the following strategy(Search) will not always yield an solution(Optimal) to its goal during a search procedure?**
   A. A* (Best-First) Search
   B. Iterative Deepening A* (Best-First) Search
   C. Greedy (Best-First) Search
   D. None of the above

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Questions?
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Answers!