# Penentuan Rute (*Route/Path Planning*)

## Bagian 1: BFS, DFS, UCS, Greedy Best First Search

Bahan Kuliah IF2211 Strategi Algoritma

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Sekolah Teknik Elektro dan Informatika ITB
2021

# Referensi

1. Materi kuliah IF3170 Inteligensi Buatan Teknik Informatika ITB, Course Website:

   http://kuliah.itb.ac.id → STEI → Teknik Informatika → IF3170

2. Stuart J Russell & Peter Norvig, *Artificial Intelligence: A Modern Approach, 3rd Edition*, Prentice-Hall International, Inc, 2010, Textbook

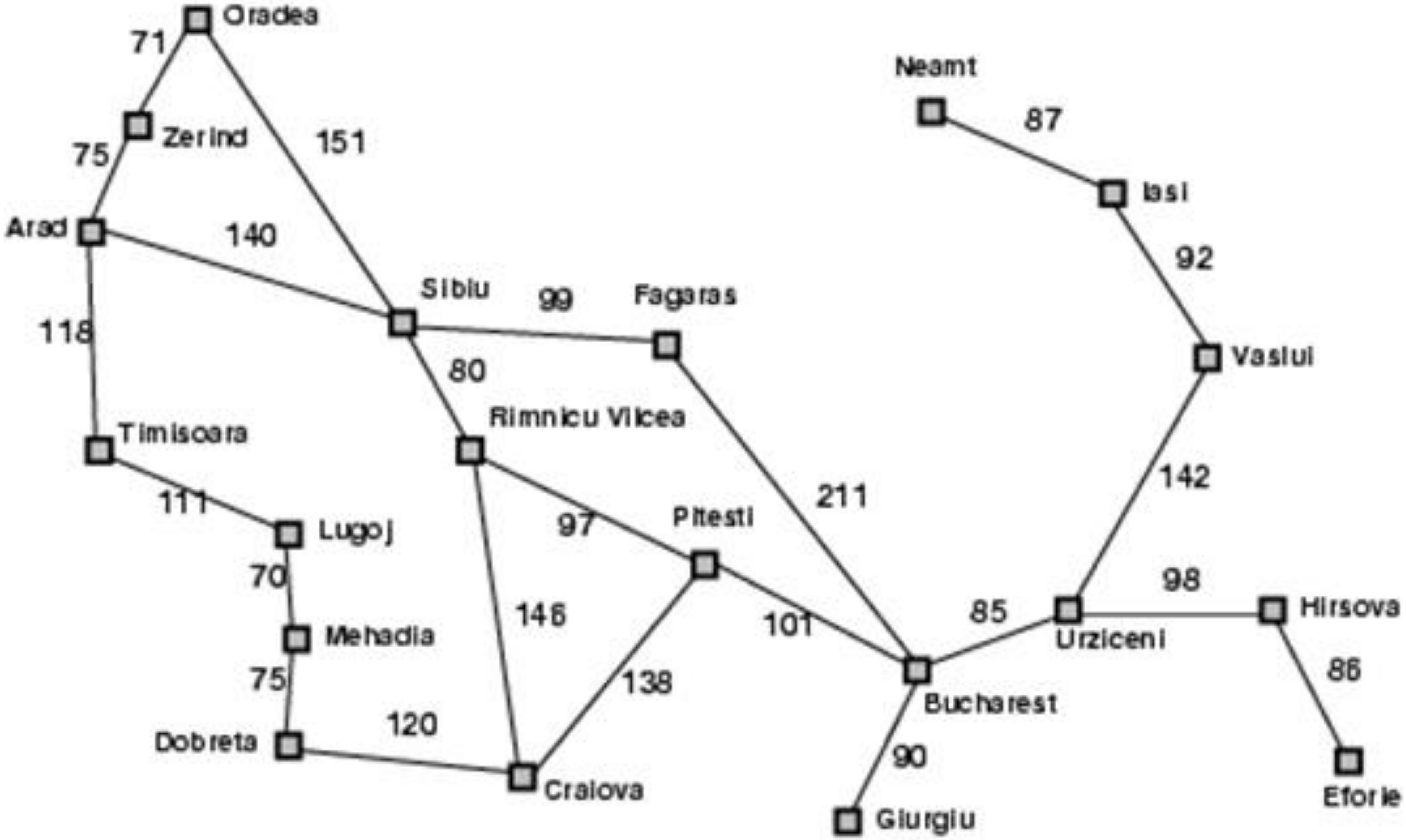
   Site: http://aima.cs.berkeley.edu/ (2nd edition)

3. Free online course materials | MIT OpenCourseWare Website: Site: http://ocw.mit.edu/courses/electrical-engineering-and-computer-science/

4. Lecture Notes in Informed Heuristic Search, ICS 271 Fall 2008, http://www.ics.uci.edu/~dechter/courses/ics-271/fall-08/lecture-notes/4.InformedHeuristicSearch.ppt

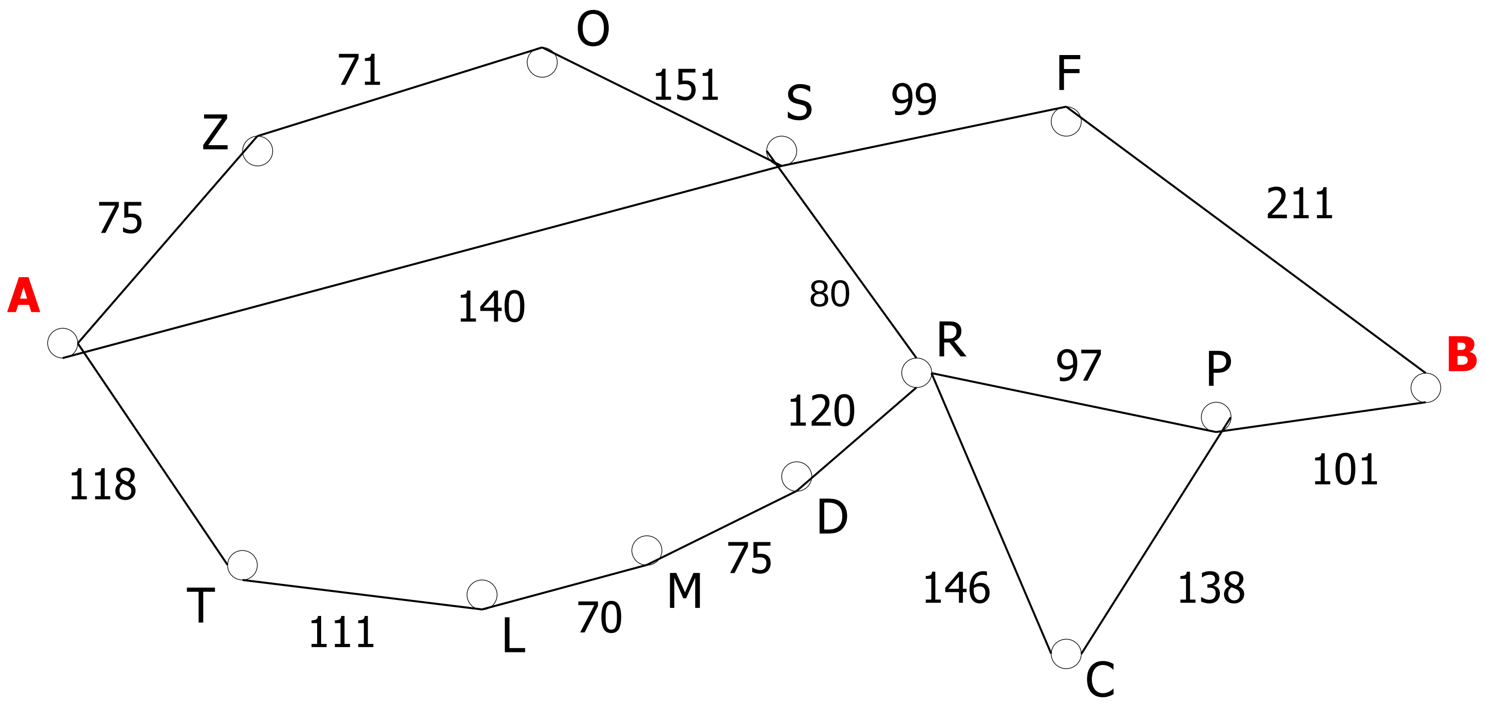
# Route Planning

HUNGARY
MOLDOVA
UKRAINE
Serbia
BULGARIA
THE FORMER YUGOSLAV REPUBLIC OF MACEDONIA
Black Sea
Bucharest
Romania
International boundary
County (judeţ) boundary
National capital
County (judeţ) center
Railroad
Expressway
Road
0 25 50 75 100 Kilometers
0 25 50 75 100 Miles


Oradea
71
Neamt
Zerind
75
151
87
Iasi
Arad
140
92
Sibiu
99
Fagaras
118
Vaslui
80
Rimnicu Vilcea
Timisoara
211
142
111
Lugoj
Pitesti
97
70
98
Hirsova
146
85
Mehadia
101
Urziceni
86
75
138
Bucharest
120
Dobreta
90
Craiova
Eforie
Giurgiu

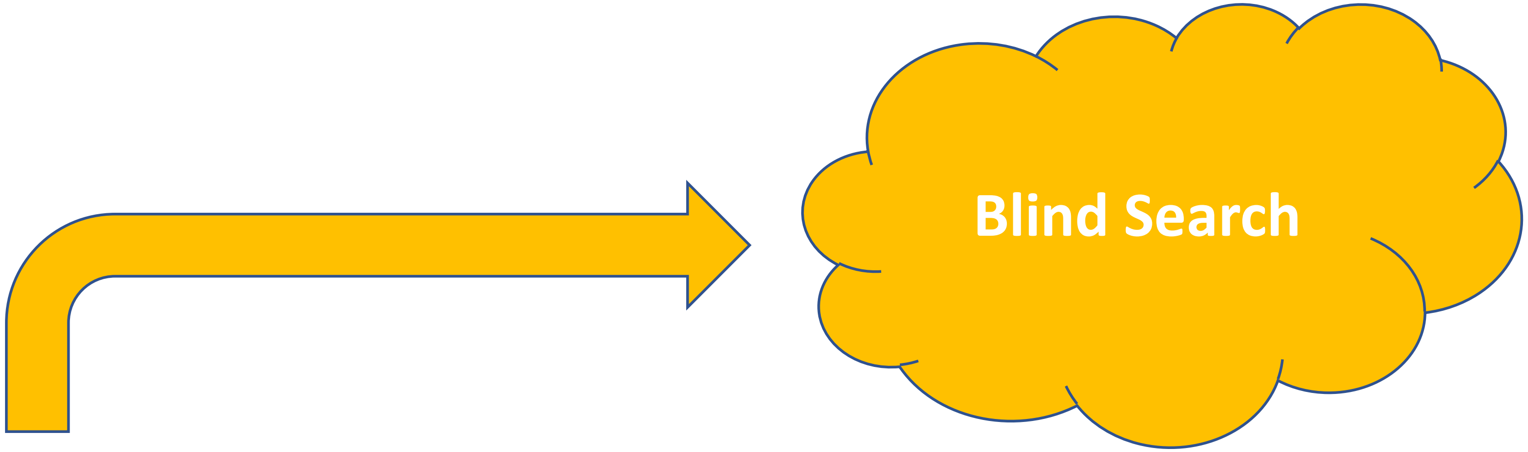
Source: Russell’s book

# Search



(a part of graph of Romania)

S: set of cities
i.s: A (Arad)
g.s: B (Bucharest)
Goal test: s = B ?
Path cost: time ~ distance



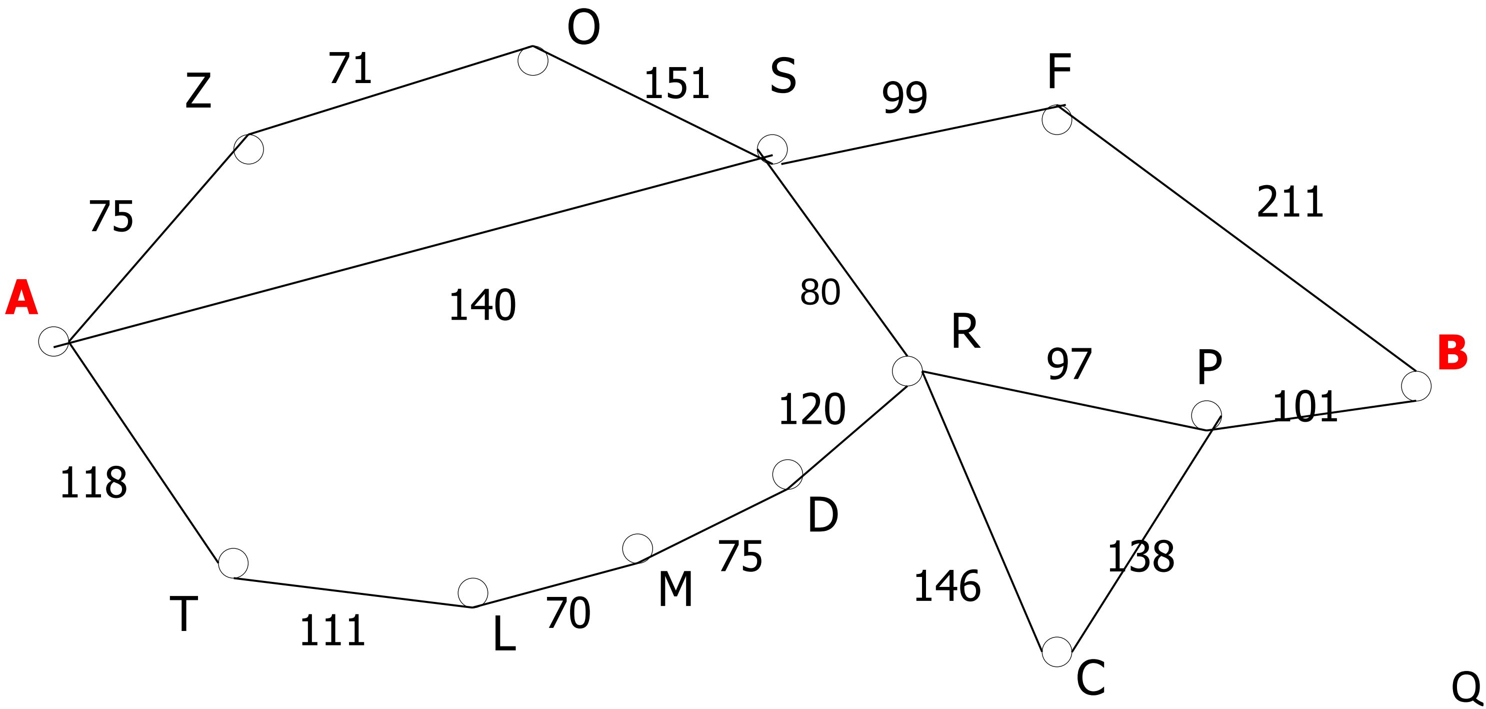
Blind Search

# Uninformed Search

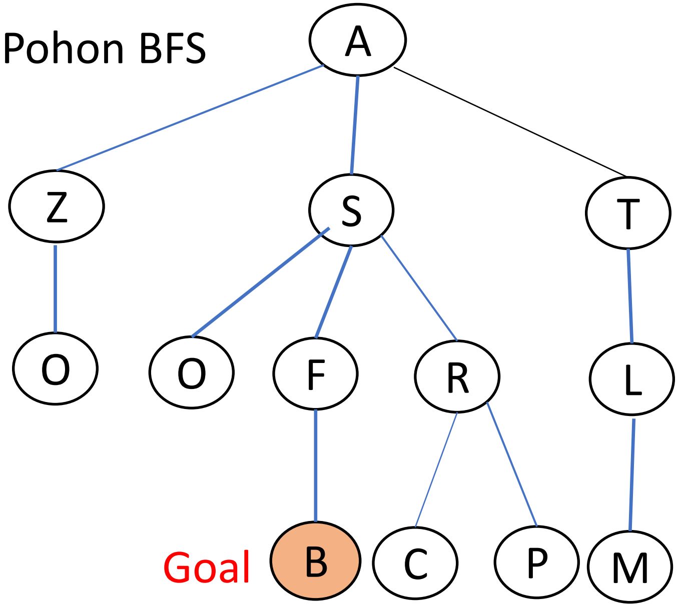
- BFS (*Breadth First Search*)
- DFS (*Depth First Search*)
- DLS (*Depth Limited Search*)
- IDS (*Iterative Deepening Search*)
- UCS (*Uniform Cost Search*)

# Breadth-First Search (BFS)

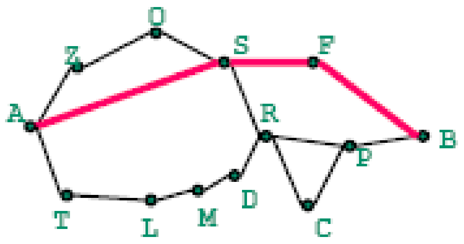
Treat agenda as a queue (FIFO)



Pohon BFS



**Path: A→ S → F → B,**
**Path-cost = 450**

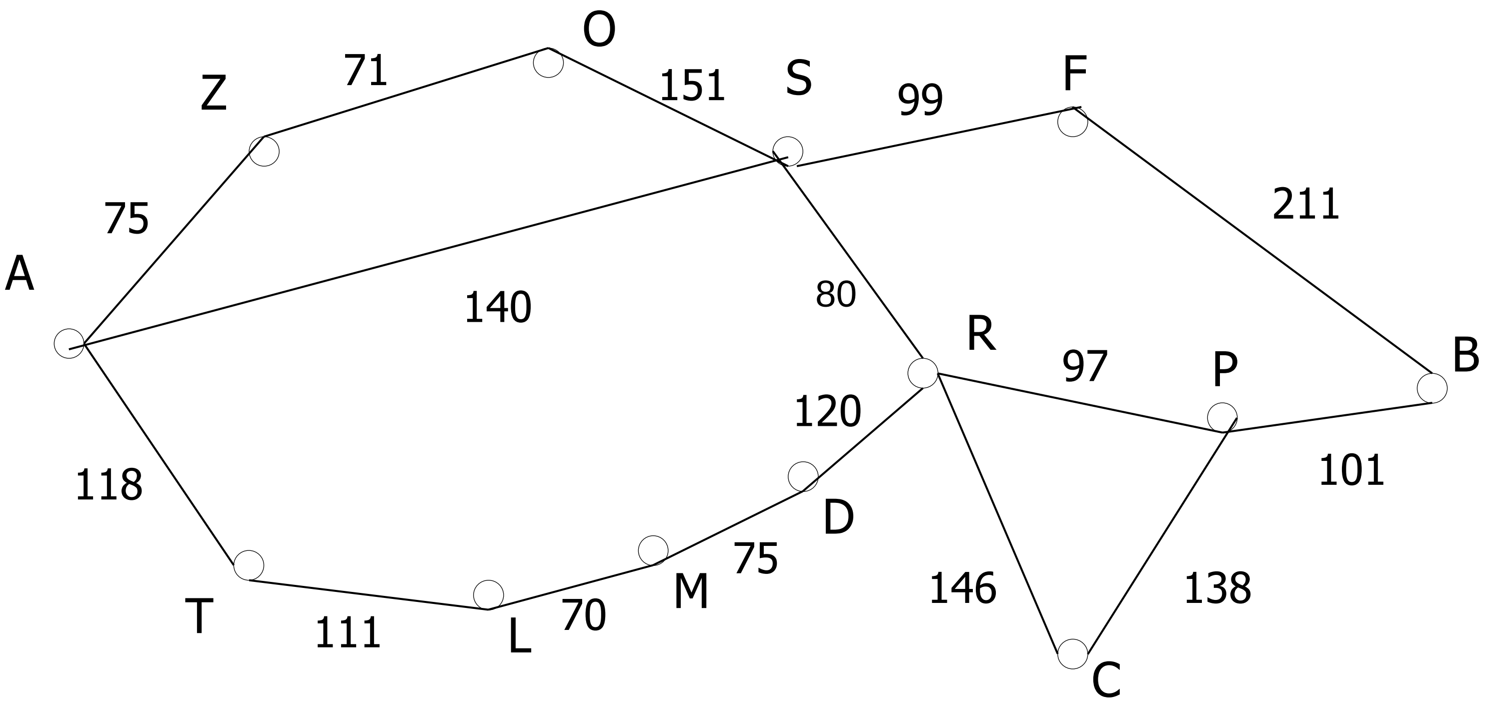


Queue

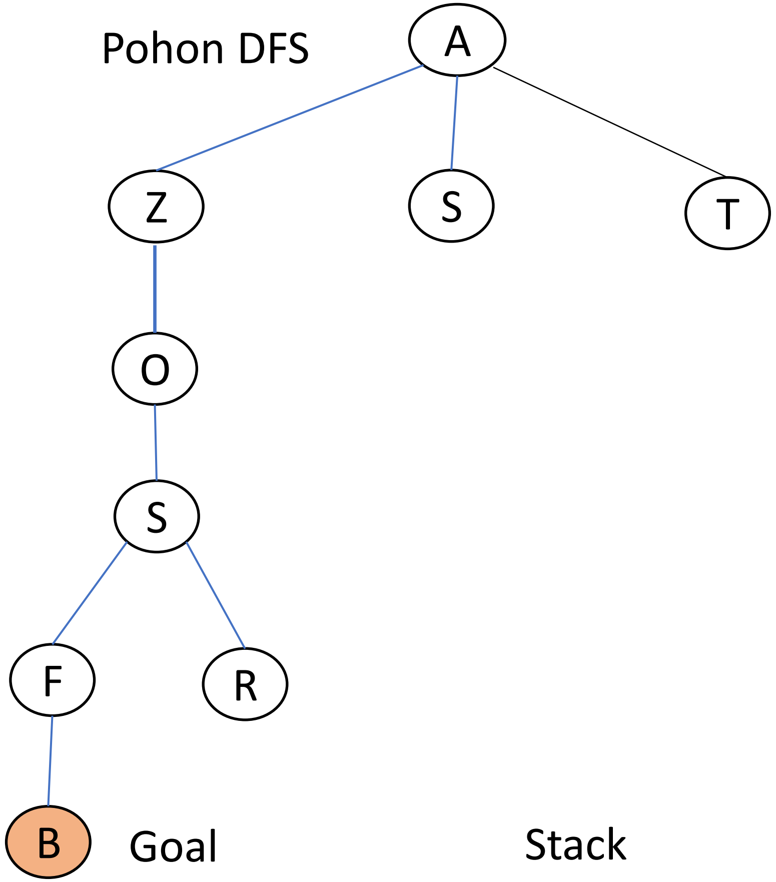
| Simpul-E | Simpul Hidup |
|---|---|
| A | $Z_A,S_A,T_A$ |
| $Z_A$ | $S_A,T_A,O_{AZ}$ |
| $S_A$ | $T_A,O_{AZ},O_{AS},F_{AS},R_{AS}$ |
| $T_A$ | $O_{AZ},O_{AS},F_{AS},R_{AS},L_{AT}$ |
| $O_{AZ}$ | $O_{AS},F_{AS},R_{AS},L_{AT}$ |
| $O_{AS}$ | $F_{AS},R_{AS},L_{AT}$ |
| $F_{AS}$ | $R_{AS},L_{AT},B_{ASF}$ |
| $R_{AS}$ | $L_{AT},B_{ASF},D_{ASR},C_{ASR},P_{ASR}$ |
| $L_{AT}$ | $B_{ASF},D_{ASR},C_{ASR},P_{ASR},M_{ATL}$ |
| $B_{ASF}$ | Solusi ketemu |

# Depth-First Search (DFS)

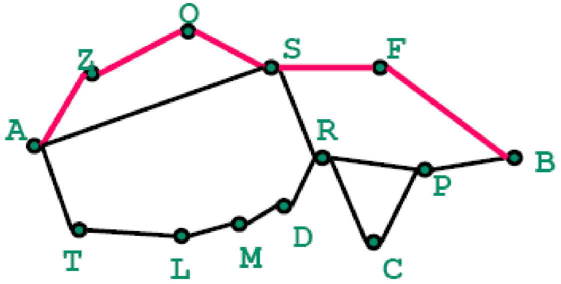
Treat agenda as a stack (LIFO)



Pohon DFS



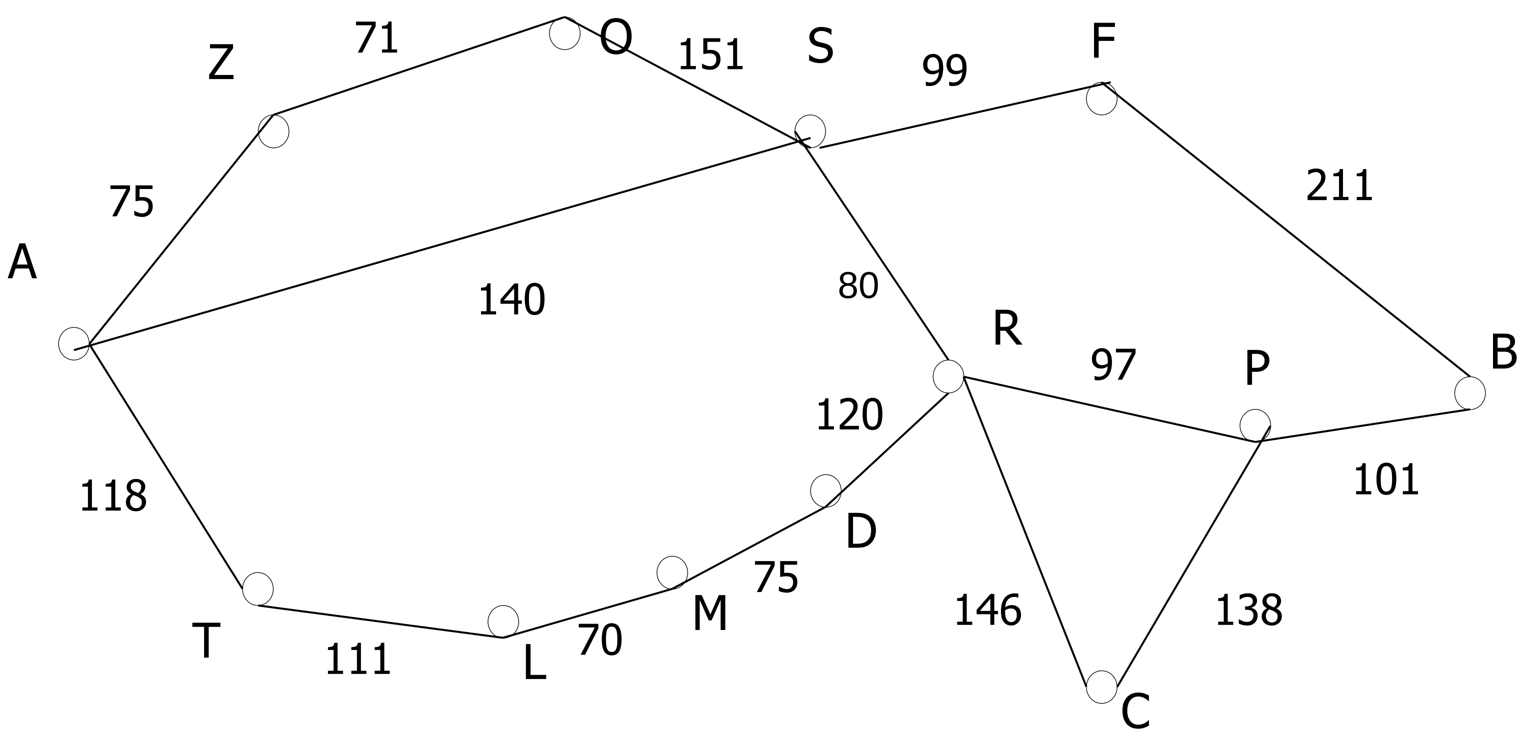
**Path: A→ Z → O → S → F → B**
**Path-cost = 607**

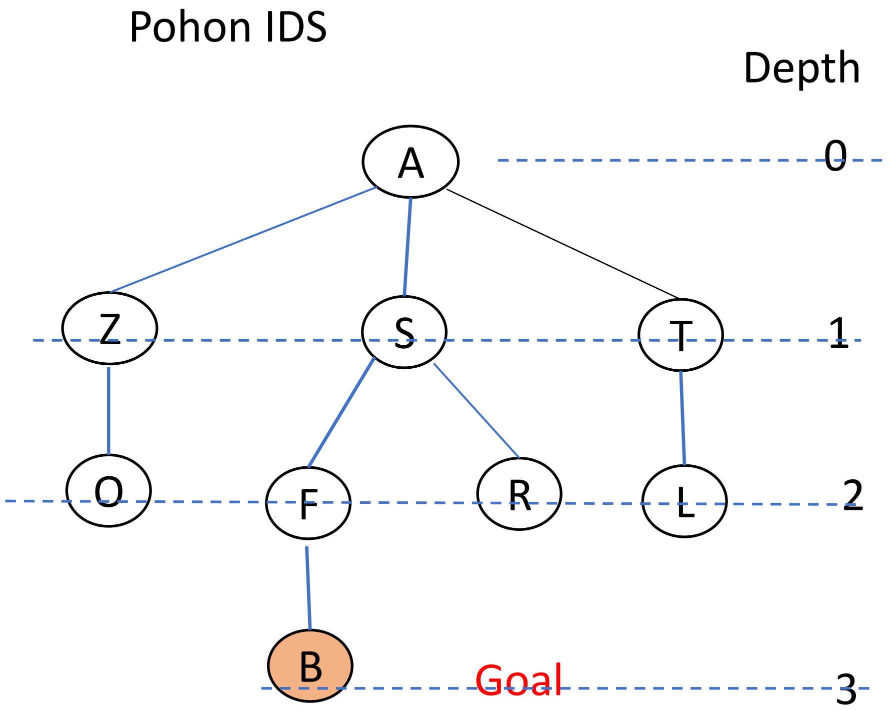


Stack

| Simpul-E | Simpul Hidup |
|---|---|
| A | $Z_A, S_A, T_A$ |
| $Z_A$ | $O_{AZ}$, $S_A, T_A$ |
| $O_{AZ}$ | $S_{AZO}, S_A, T_A$ |
| $S_{AZO}$ | $F_{AZOS}$, $R_{AZOS}, S_A, T_A$ |
| $F_{AZOS}$ | $B_{AZOSF}$, $R_{AZOS}, S_A, T_A$ |
| $B_{AZOSF}$ | Solusi ketemu |

# Iterative Deepening Search (IDS)





Depth=0: A: cutoff

Depth=1: A → $Z_A$,$S_A$,$T_A$ → $Z_A$: cutoff, $S_A$: cutoff, $T_A$: cutoff

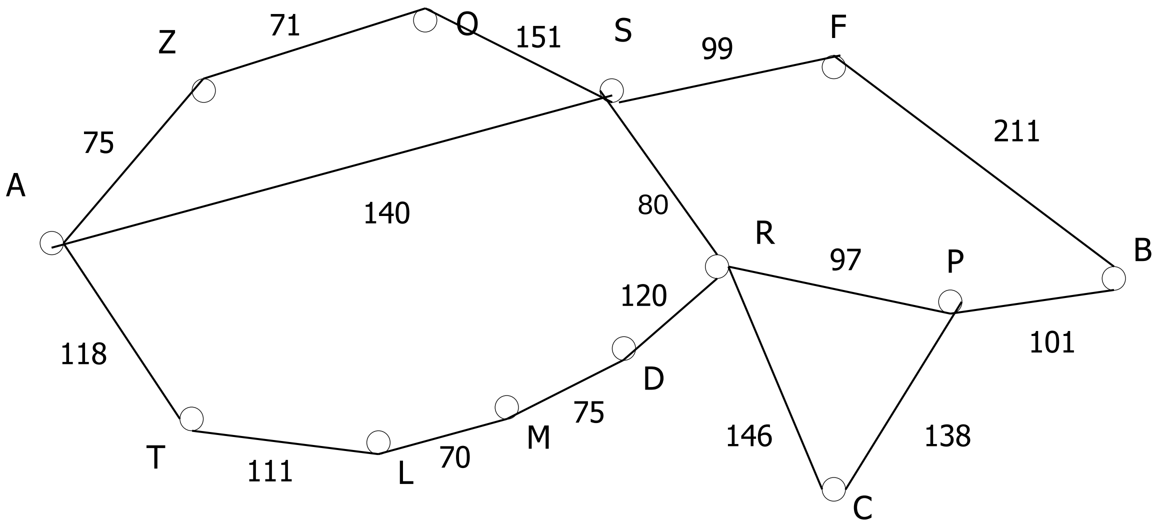
Depth=2: A → $Z_A$,$S_A$,$T_A$ → $O_{AZ}$, $S_A$,$T_A$ → $O_{AZ}$ : cutoff → $F_{AS}$, $R_{AS}$,$T_A$ → $F_{AS}$ : cutoff → $R_{AS}$ : cutoff → $L_{AT}$
→ $L_{AT}$ : cutoff

Depth=3: A → $Z_A$,$S_A$,$T_A$ → $O_{AZ}$, $S_A$,$T_A$ → $S_{AZO}$,$S_A$,$T_A$ → $S_{AZO}$: cutoff → $F_{AS}$, $R_{AS}$,$T_A$ → $B_{ASF}$, $R_{AS}$,$T_A$ → $B_{ASF}$

**Stop: B=goal, path: A→ S → F → B, path-cost = 450**

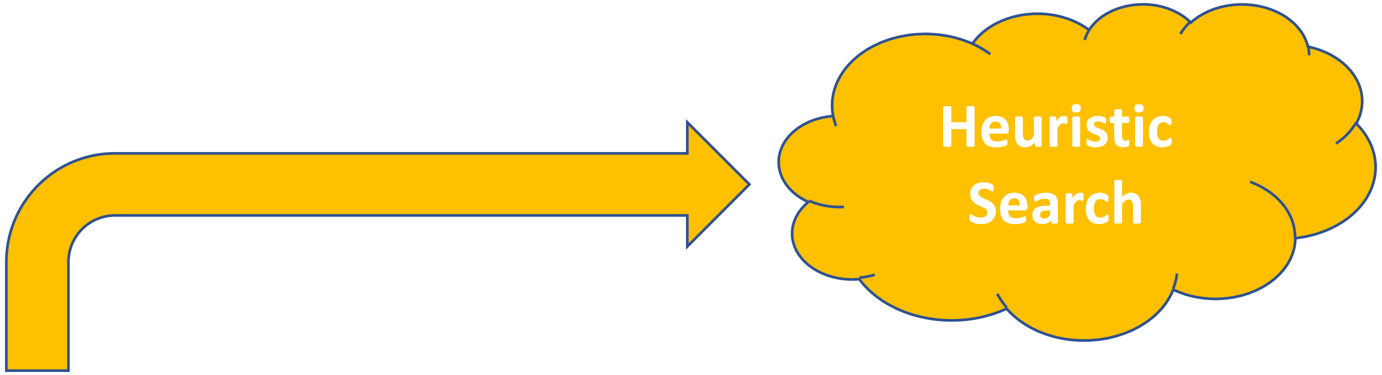
# Uniform Cost Search (UCS)

- BFS & IDS find path with fewest steps (A-S-F-B)
- If steps ≠ cost, this is not relevant (to optimal solution)
- How can we find the shortest path (measured by sum of distances along path)?
- *g*(*n*) = path cost from root to *n*



**Path: A→ S → R → P → B**
**Path-cost = 418 → optimal solution**

| Simpul-E | Simpul Hidup |
|---|---|
| A | $Z_{A-75}$, $T_{A-118,}$ $S_{A-140}$ |
| $Z_{A-75}$ | $T_{A-118}$, $S_{A-140}$, $O_{AZ-146}$ |
| $T_{A-118}$ | $S_{A-140}$, $O_{AZ-146}$, $L_{AT-229}$ |
| $S_{A-140}$ | $O_{AZ-146}$, $R_{AS-220}$, $L_{AT-229}$, $F_{AS-239}$, $O_{AS-291}$ |
| $O_{AZ-146}$ | $R_{AS-220}$, $L_{AT-229}$, $F_{AS-239}$, $O_{AS-291}$ |
| $R_{AS-220}$ | $L_{AT-229}$, $F_{AS-239}$, $O_{AS-291}$, $P_{ASR-317}$, $D_{ASR-340}$, $C_{ASR-366}$ |
| $L_{AT-229}$ | $F_{AS-239}$, $O_{AS-291}$, $M_{ATL-299}$, $P_{ASR-317}$, $D_{ASR-340}$, $C_{ASR-366}$ |
| $F_{AS-239}$ | $O_{AS-291}$, $M_{ATL-299}$, $P_{ASR-317}$, $D_{ASR-340}$, $C_{ASR-366,}$ $B_{ASF-450}$ |
| $O_{AS-291}$ | $M_{ATL-299}$, $P_{ASR-317}$, $D_{ASR-340}$, $C_{ASR-366,}$ $B_{ASF-450}$ |
| $M_{ATL-299}$ | $P_{ASR-317}$, $D_{ASR-340}$, $D_{ATLM-364}$, $C_{ASR-366,}$ $B_{ASF-450}$ |
| $P_{ASR-317}$ | $D_{ASR-340}$, $D_{ATLM-364}$, $C_{ASR-366,}$ $B_{ASRP-418}$, $C_{ASRP-455,}$ $B_{ASF-450}$ |
| $D_{ASR-340}$ | $D_{ATLM-364}$, $C_{ASR-366,}$ $B_{ASRP-418}$, $C_{ASRP-455,}$ $B_{ASF-450}$ |
| $D_{ATLM-364}$ | $C_{ASR-366,}$ $B_{ASRP-418}$, $C_{ASRP-455,}$ $B_{ASF-450}$ |
| $C_{ASR-366}$ | $B_{ASRP-418}$, $C_{ASRP-455,}$ $B_{ASF-450}$ |
| $B_{ASRP-418}$ | Solusi ketemu |



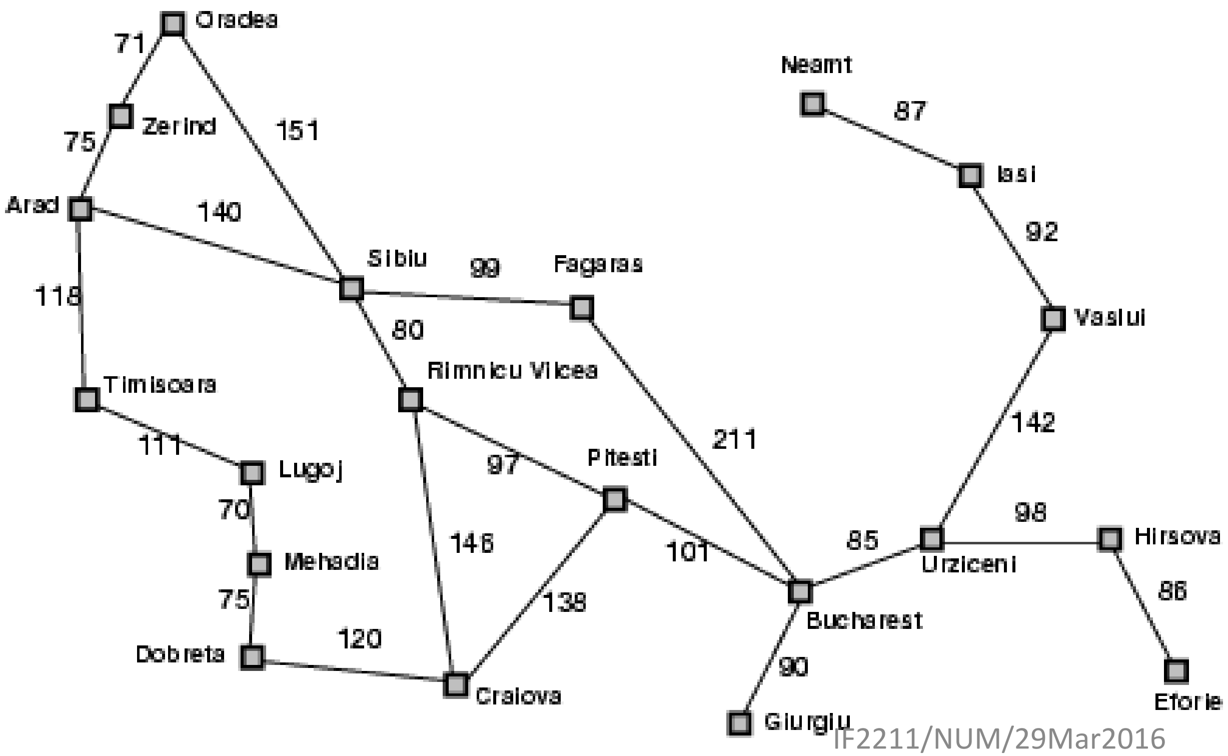
Heuristic Search

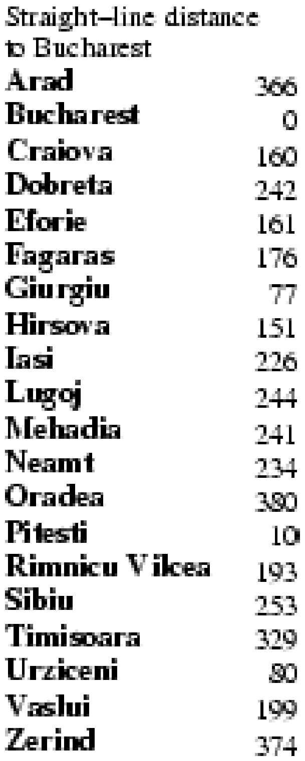
# Informed Search

- Greedy Best First Search
- A*

# Greedy Best-First Search

- Idea: use an evaluation function *f(n)* for each node
  - *f(n) = h(n) → estimates of cost from n to goal*
  - e.g., $h_{SLD}(n)$ = straight-line distance from *n* to Bucharest
- Greedy best-first search expands the node that appears to be closest to goal



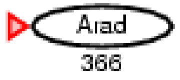


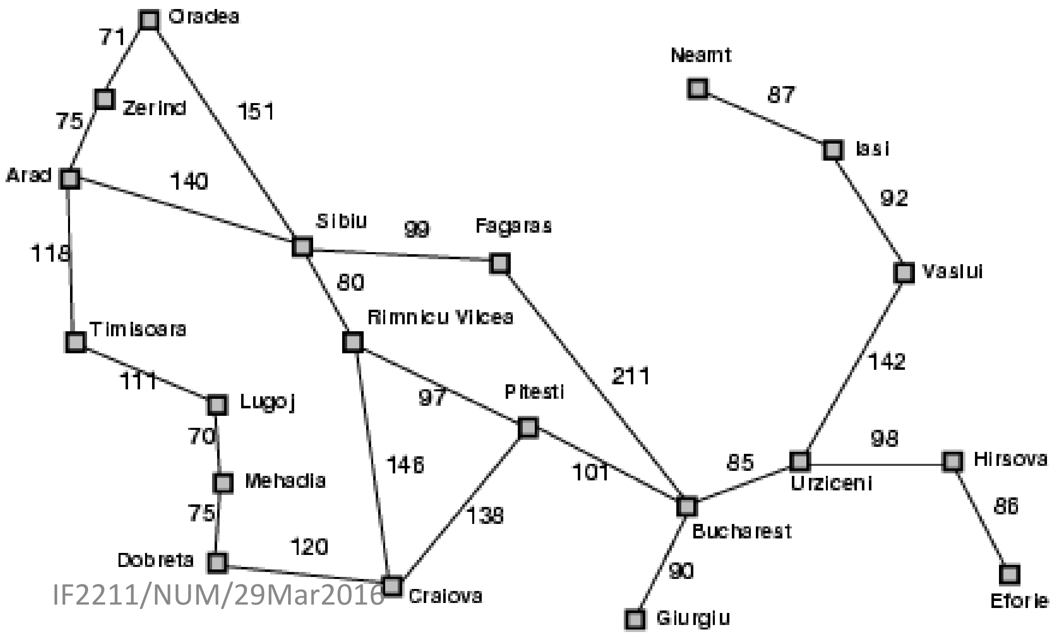
Straight–line distance to Bucharest

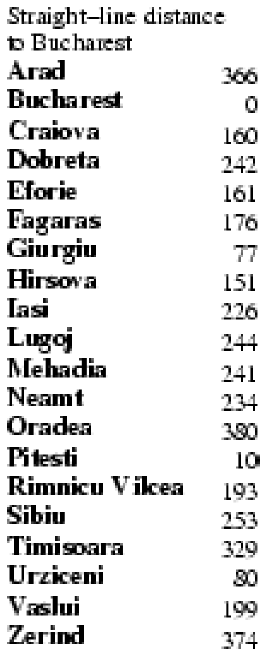
| | |
|---|---|
| **Arad** | 366 |
| **Bucharest** | 0 |
| **Craiova** | 160 |
| **Dobreta** | 242 |
| **Eforie** | 161 |
| **Fagaras** | 176 |
| **Giurgiu** | 77 |
| **Hirsova** | 151 |
| **Iasi** | 226 |
| **Lugoj** | 244 |
| **Mehadia** | 241 |
| **Neamt** | 234 |
| **Oradea** | 380 |
| **Pitesti** | 10 |
| **Rimnicu Vilcea** | 193 |
| **Sibiu** | 253 |
| **Timisoara** | 329 |
| **Urziceni** | 80 |
| **Vaslui** | 199 |
| **Zerind** | 374 |

Romania with step costs in km:

# Greedy best-first search example







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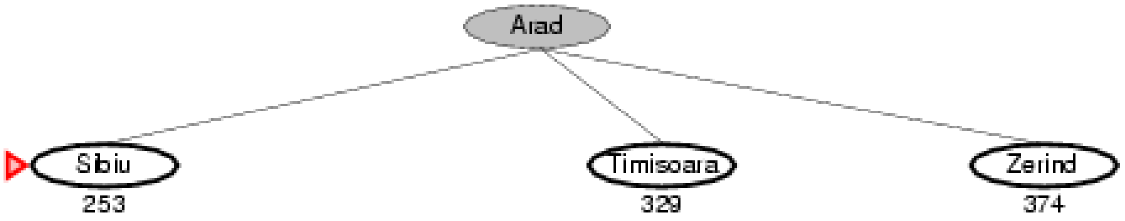
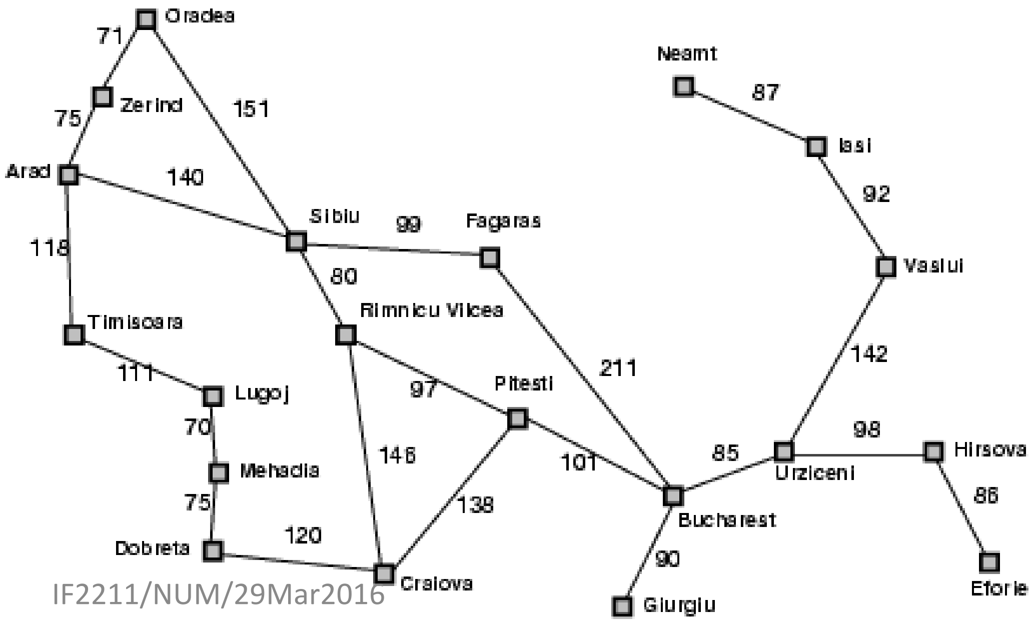
# Greedy best-first search example





Straight–line distance
to Bucharest

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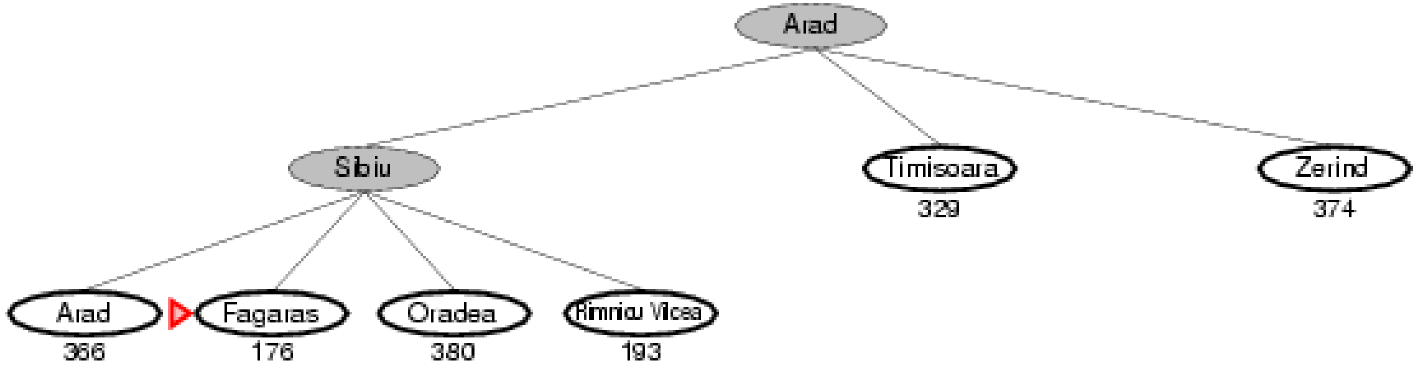
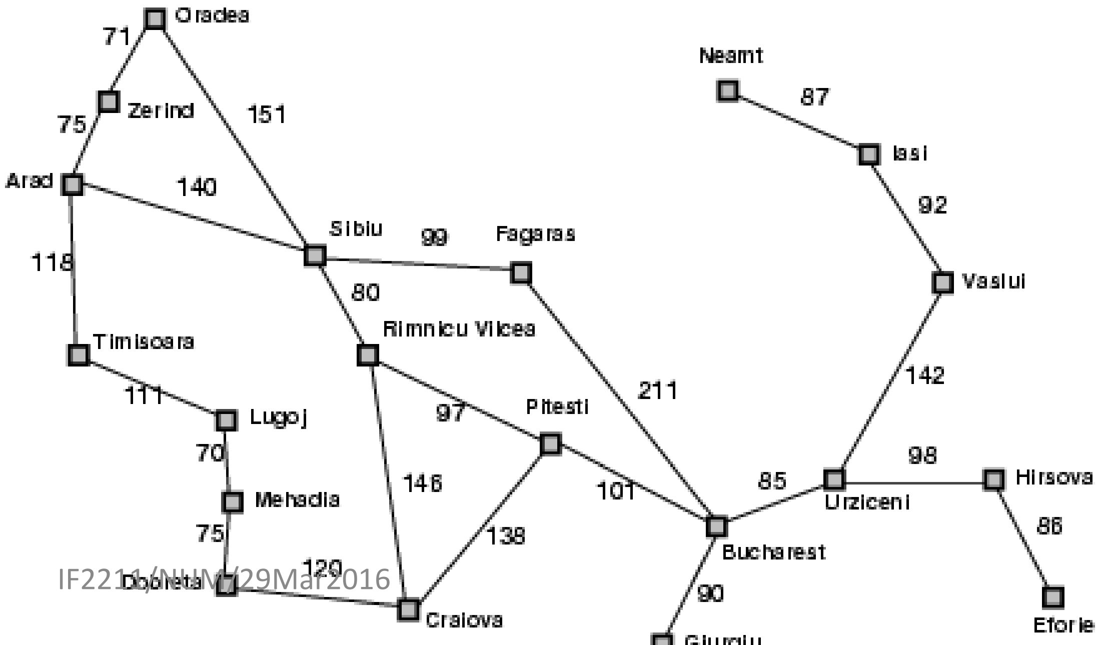
# Greedy best-first search example





Straight–line distance
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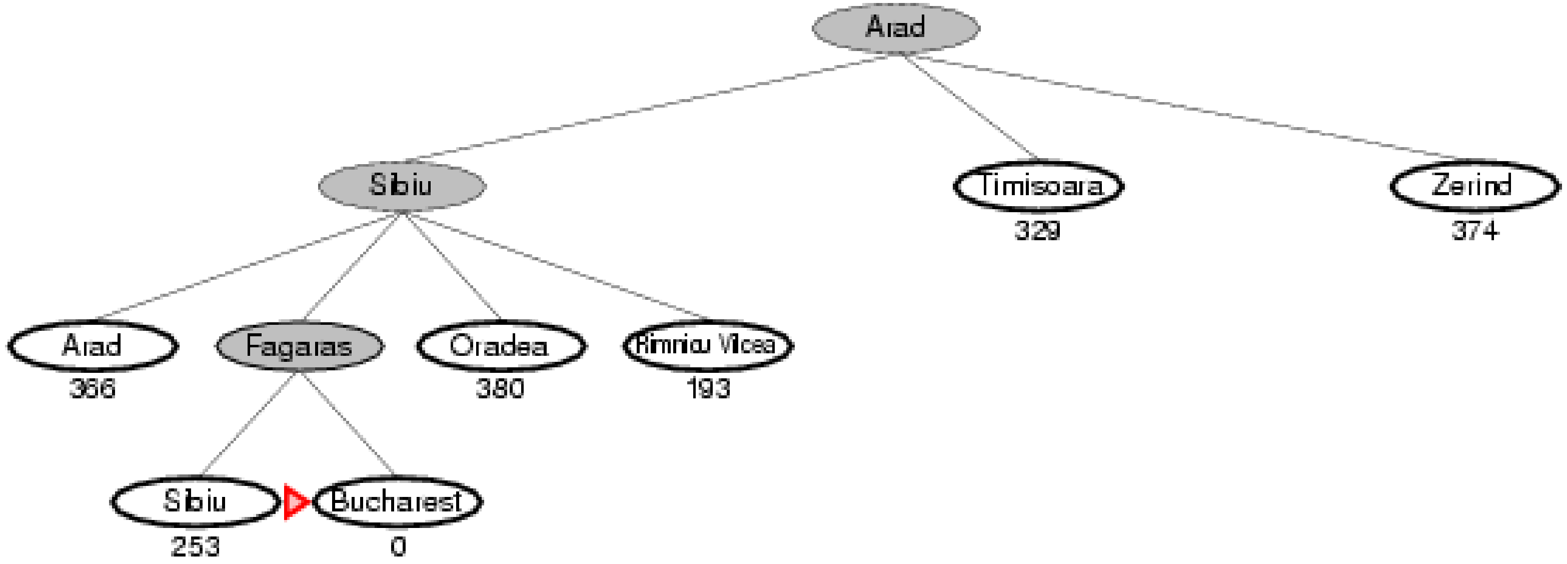
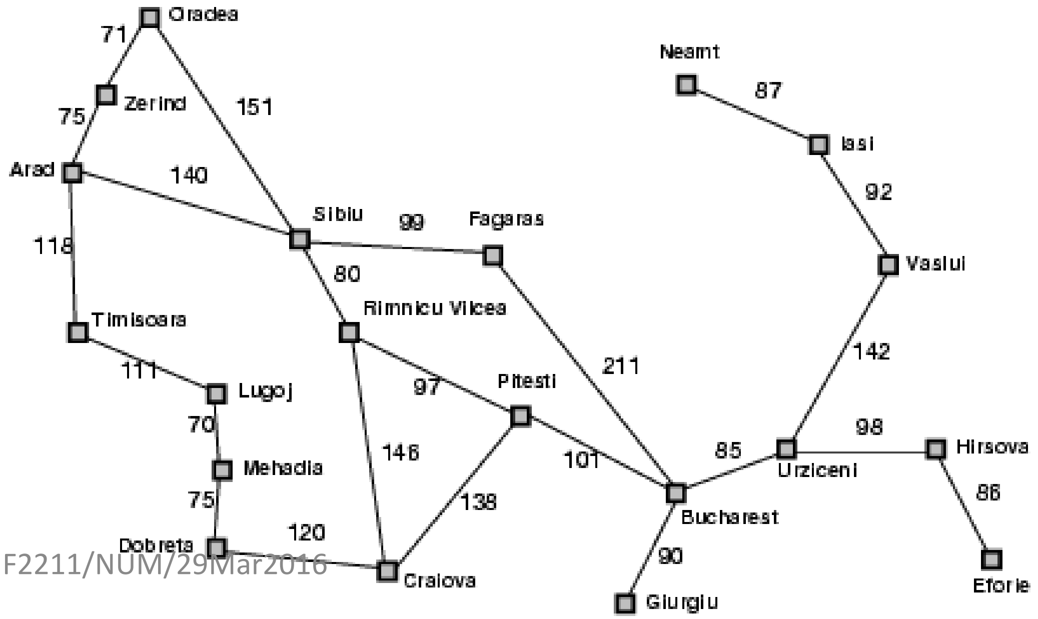
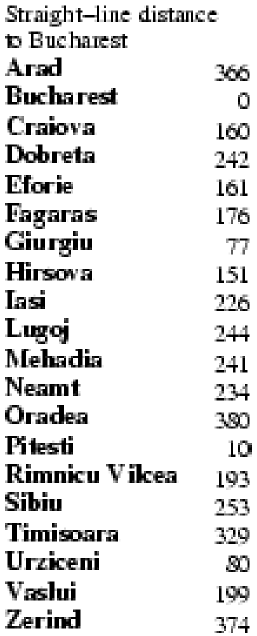
| **Sibiu** | 253 |
| **Timisoara** | 329 |
| **Urziceni** | 80 |
| **Vaslui** | 199 |
| **Zerind** | [illegible] |

# Greedy best-first search example







Straight–line distance to Bucharest

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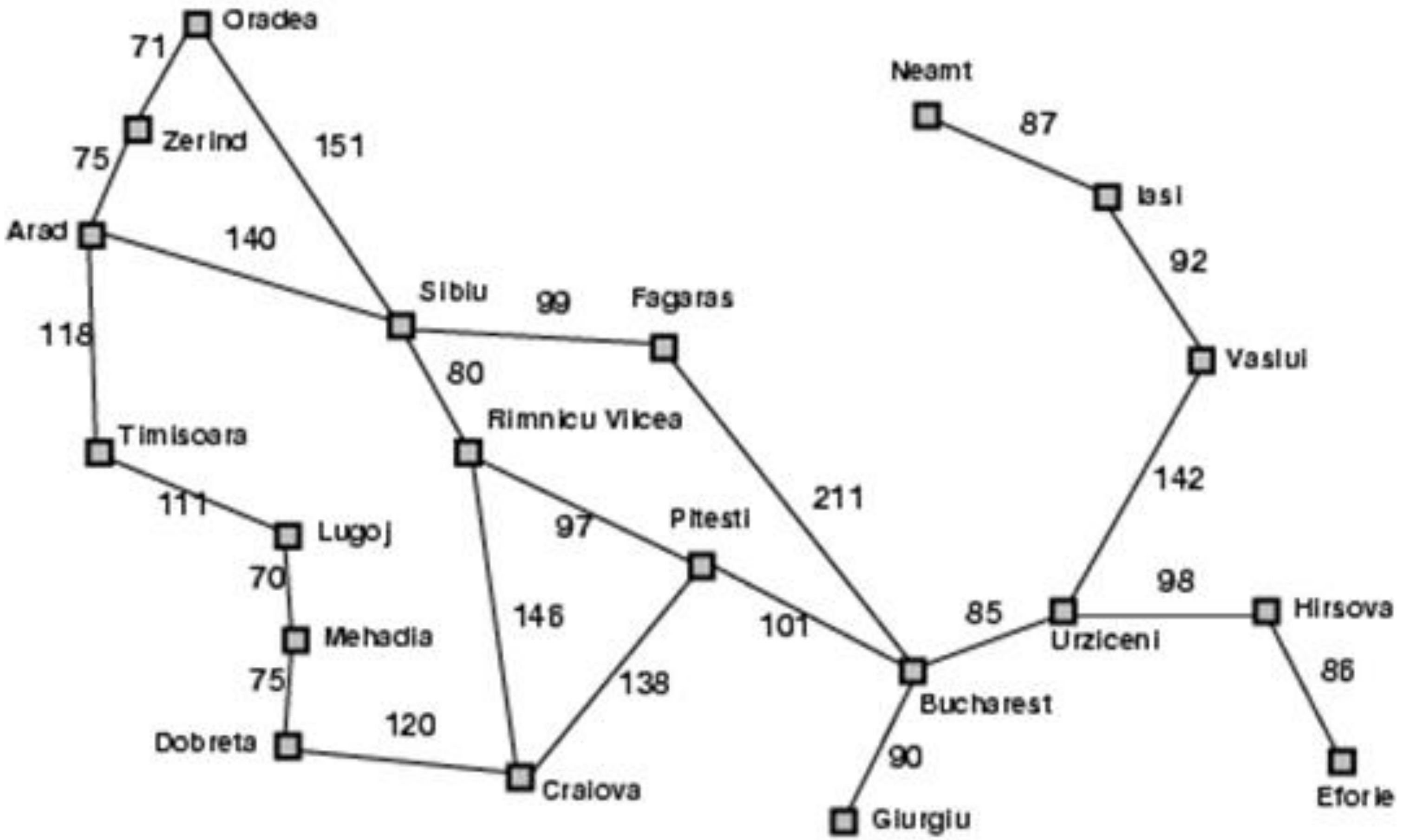
| Timisoara | 329 |
| Urziceni | 80 |
| Vaslui | 199 |
| Zerind | 374 |

**Path: Arad→ Sibiu → Fagaras → Bucharest,**
**Path-cost = 450 → not optimal solution**

# Problems with Greedy Best First Search

1. Not complete



Lasi to Fragaras?

# Problems with Greedy Best First Search

2. Get stuck with local minima/plateu
3. Irrevocable (not able to be reversed/changed)
4. Can we incorporate heuristics in systematic search?

(Bersambung pada Bagian 2)