

Planning and Optimization

X2. Hands-On and Repetition

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X2.1 Heuristics

X2.2 A* Search Algorithm

X2.3 Hands-On

Hands-On: Overview

Chapter overview: hands-on

- ▶ 1. The Planning Domain Definition Language (PDDL)
- ▶ 2. Getting to Know a Planner
- ▶ 3. Heuristics
- ▶ 4. A* search algorithm

X2.1 Heuristics

Heuristics

Definition (heuristic)

Let \mathcal{S} be a state space with set of states S .

A **heuristic function** or **heuristic** for \mathcal{S} is a function

$$h : S \rightarrow \mathbb{R}_0^+ \cup \{\infty\},$$

mapping each state to a non-negative number (or ∞).

Heuristics: Intuition

idea: $h(s)$ estimates cost of cheapest path from s to closest goal state

- ▶ heuristics can be **arbitrary** functions
- ▶ **intuition:** the closer h is to true cost to goal, the more efficient the search using h

X2.2 A* Search Algorithm

A* Search Algorithm

A* search algorithm

- ▶ based on heuristic h , define evaluation function f for node n :
 $f(n) := g(n) + h(n.state)$
- ▶ trade-off between path cost and estimated proximity to goal
- ▶ intuition: $f(n)$ estimates costs of cheapest solution from initial state through $n.state$ to goal

A* Search Algorithm: Pseudo-Code

A* search algorithm (with re-opening)

```

open := new priority queue, ordered by  $\langle f, h \rangle$ 
if  $h(\text{init-state}) < \infty$ :
    open.insert(make_root_node())
distances := new HashTable
while not open.empty():
    n = open.pop-min()
    if (not distances.contains(n.state)) or  $(g(n) < \text{distances}[n.state])$ :
        distances[n.state] :=  $g(n)$ 
        if is-goal(n.state):
            return extract-solution(n)
        for each successor  $\langle a, s' \rangle$  of n.state:
            if  $h(s') < \infty$ :
                n' := make_node(n, a, s')
                open.insert(n')
return unsolvable

```

A* Search Algorithm

Most important property

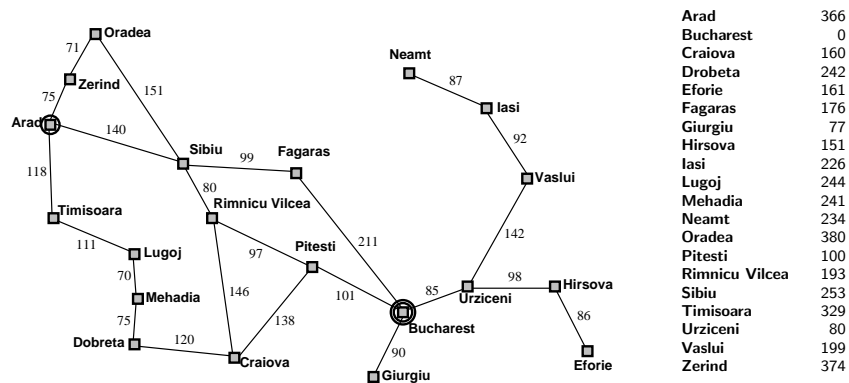
- ▶ A* is **optimal** if the applied heuristic is **admissible**.

For more details on best-first search and A*, see chapter 15–19 of the AI course last semester.

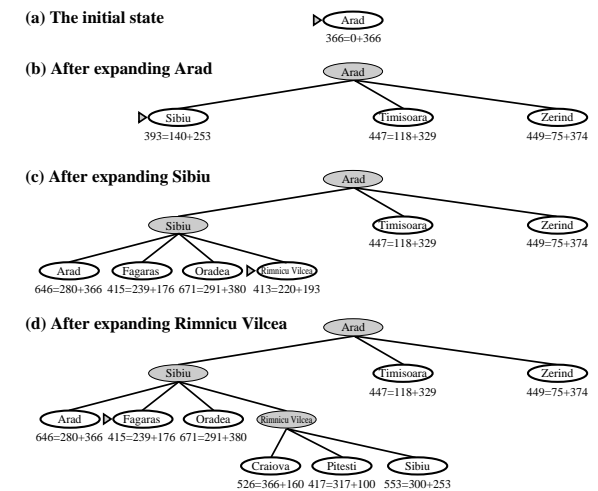
(<http://informatik.unibas.ch/fs2016/grundlagen-der-kuenstlichen-intelligenz/>)

Example: A* for Route Planning

Example heuristic: straight-line distance to Bucharest

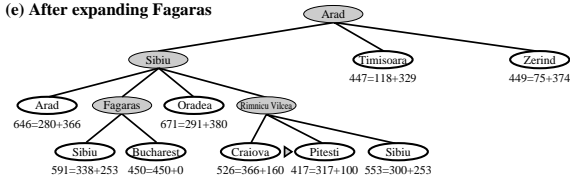


Example: A* for Route Planning

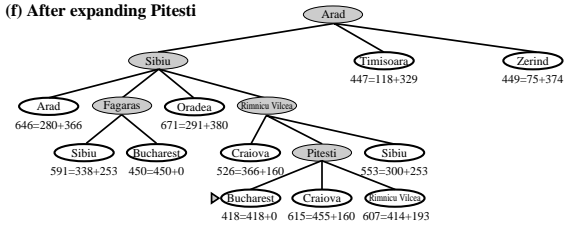


Example: A* for Route Planning

(e) After expanding Fagaras



(f) After expanding Pitesti



X2.3 Hands-On