6.4110
Spring 2026 Recitation 5 Handout

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Relaxed Planning Graph (RPG)

A Relaxed Planning Graph is constructed by **ignoring delete effects**. Facts therefore accumulate monotonically across layers.
Layers alternate between:

- Fact layers F_t: fluents that may be true at time t
- Action layers A_t: actions whose preconditions are satisfied in F_t

Definitions:

$$RPG.level(f) = \min\{t \mid f \in F_t\}$$

$$RPG.level(a) = \min\{t \mid a \in A_t\}$$

i.e., the earliest layer where a fact becomes true or an action becomes applicable.

h_{max} Heuristic

For a fact f:

$$cost(f) = \begin{cases} 0 & \text{if } f \text{ is already true} \\ \min\limits_{a \in Ach(f)} \left(1 + \max\limits_{p \in pre(a)} cost(p)\right) & \end{cases}$$

For a goal set G:

$$h_{max}(G) = \max_{g \in G} cost(g)$$

h_{add} Heuristic

For a fact f:

$$cost(f) = \begin{cases} 0 & \text{if } f \text{ is already true} \\ \min\limits_{a \in Ach(f)} \left(1 + \sum\limits_{p \in pre(a)} cost(p)\right) & \end{cases}$$

For a goal set G:

$$h_{add}(G) = \sum_{g \in G} cost(g)$$

h_{FF} (Fast Forward Heuristic)

Steps:

1. Build the RPG until all goals appear.
2. Let $M = \max_{f \in G} RPG.level(f)$.
3. Work backwards from level M.
4. For each goal f at level t, choose an action a such that

$$RPG.level(a) = t - 1, \quad f \in add(a)$$

5. Add a to the plan.
6. Add all preconditions of a as new goals.

The heuristic value is

$$h_{FF}(s) = |\text{relaxed plan}|$$

Comparison of RPG Heuristics

Heuristic	Goal Combination	Admissible
h_{max}	max of goal costs	Yes
h_{add}	Sum of goal costs	No
h_{FF}	Relaxed plan extraction	No

1 RPG and Heuristics Example Problem

Simplified Air Cargo transport (modified from AIMA 11.1.1)

Init
$At(C_1, JFK) \land At(P_1, SFO)$
$\land Cargo(C_1) \land Plane(P_1)$
$\land Airport(JFK) \land Airport(SFO)$
Goal
$At(C_1, SFO) \land At(P_1, JFK)$
Action
Load(c,p,a)
PRECOND: $At(c, a) \land At(p, a) \land Cargo(c) \land Plane(p) \land Airport(a)$
EFFECT: $\neg At(c, a) \land In(c, p)$
Unload(c, p, a)
PRECOND: $In(c, p) \land At(p, a) \land Cargo(c) \land Plane(p) \land Airport(a)$
EFFECT: $At(c, a) \land \neg In(c, p)$
Fly(p, from, to)
PRECOND: $At(p, from) \land Plane(p) \land Airport(from) \land Airport(to)$
EFFECT: $\neg At(p, from) \land At(p, to)$

1.1 Relaxed Planning Graph (RPG)

Draw the RPG. Unary predicates for type specification can be ignored.

1.2 Heuristics

1.2.1 H_{max}

Compute the h_{max} heuristic value.

1.2.2 H_{add}

Compute the h_{add} heuristic value.

1.2.3 H_{ff}

Extract a relaxed plan and compute h_{ff}.