COMP90054
AI planning Autonomy
Workshop 5

Geye Guo

Recap: Manhattan Grid Problem

- Consider an $m \times m$ **Manhattan Grid**, and a set of coordinates G to visit in any order.
- **Hint**: Consider a set of coordinates V' remaining to be visited, or a set of coordinates V already visited. What's the difference between them
- Formulate a state-based search problem to find a tour of all the desired points (i.e. define a state space, applicable actions, transition and cost functions).

Common Heuristic for Manhattan Grid Problems

- Goal counting: h = |V’|
- Manhattan to the closest: h = min(Manhattan(all food))
- Manhattan to the furthest: h = max(Manhattan(all food))
- Average Manhattan: h = average(min, max Manhattan)
- Manhattan: h = Manhattan(all food))
- Minimum Spanning Tree: h = len(minimum spanning tree(all food))

Revision on Relaxation

- Initial STRIPS model: P = <F,O,I,G> ==> h
- After applying some transition: P’ = <F, O’, I, G>, ==> h'
- If change is relaxation, then the h’ is guaranteed to be admissible and consistent

----
-

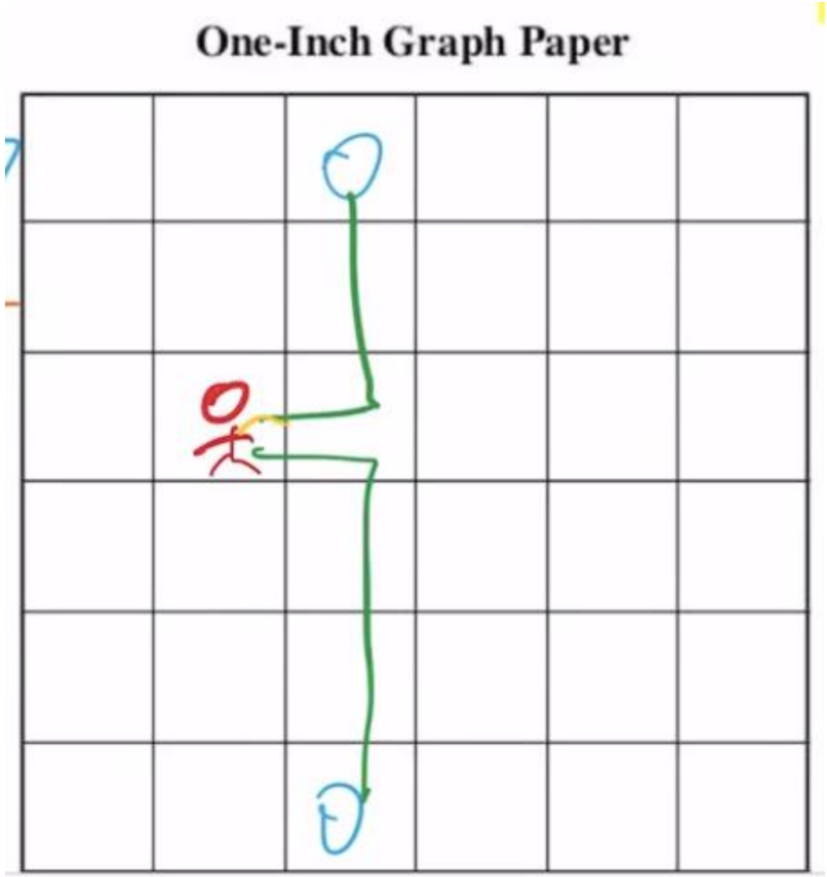
Example: Precondition and delete relaxation

- General Idea: Ignore delete and precondition lists, only keep add lists
- Then P' becomes a Subset sum problem
- Bad news!! It is still an NP-hard problem

Common Heuristic for Manhattan Problems

- Goal counting: h = |V’|
- Manhattan to the closest: h = min(Manhattan(all food))
- Manhattan to the furthest: h = max(Manhattan(all food))
- Average Manhattan: h = average(min, max)
- Manhattan: h = Manhattan(all food)
- Minimum Spanning Tree: h = len(minimum spanning tree(all food))

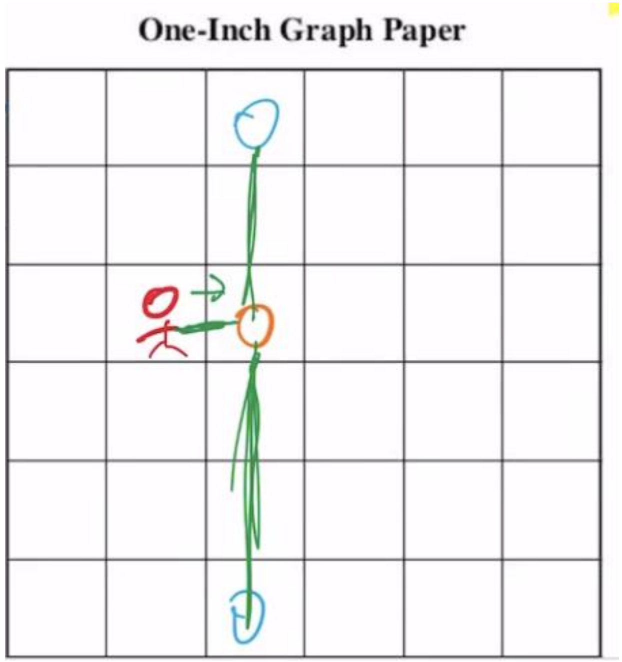
The problem of Minimum Spanning Tree



It is not consistent

Minimum Steiner Tree

- **Idea**: add extra node along the path
- **How to derive from the original?** Delete relaxation: h+
- **Is it easier to compute the minimum Steiner Tree?**

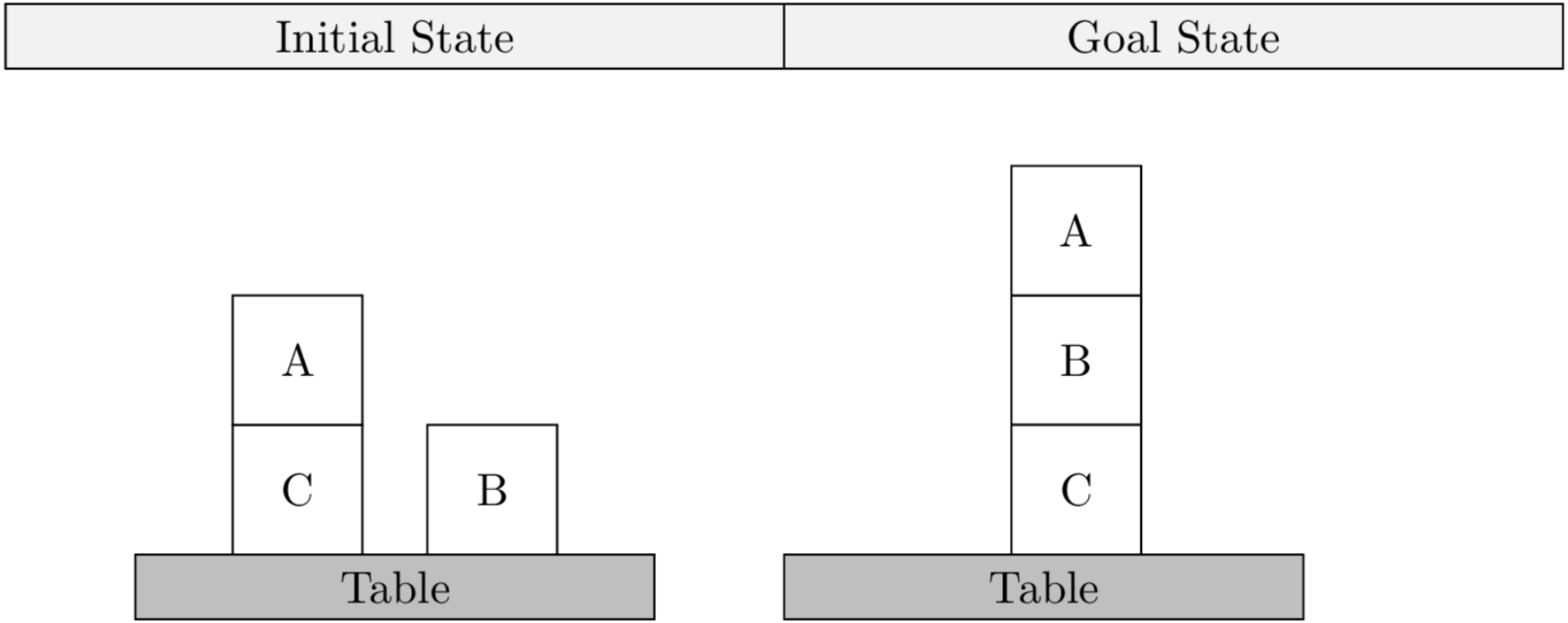


Problem 1

1. What is the (optimal) delete relaxation heuristic $h+$? How would it be interpreted in pacman?
2. What is the relationship between $hmax$, $h+$, and $hadd$? What about $h*$?

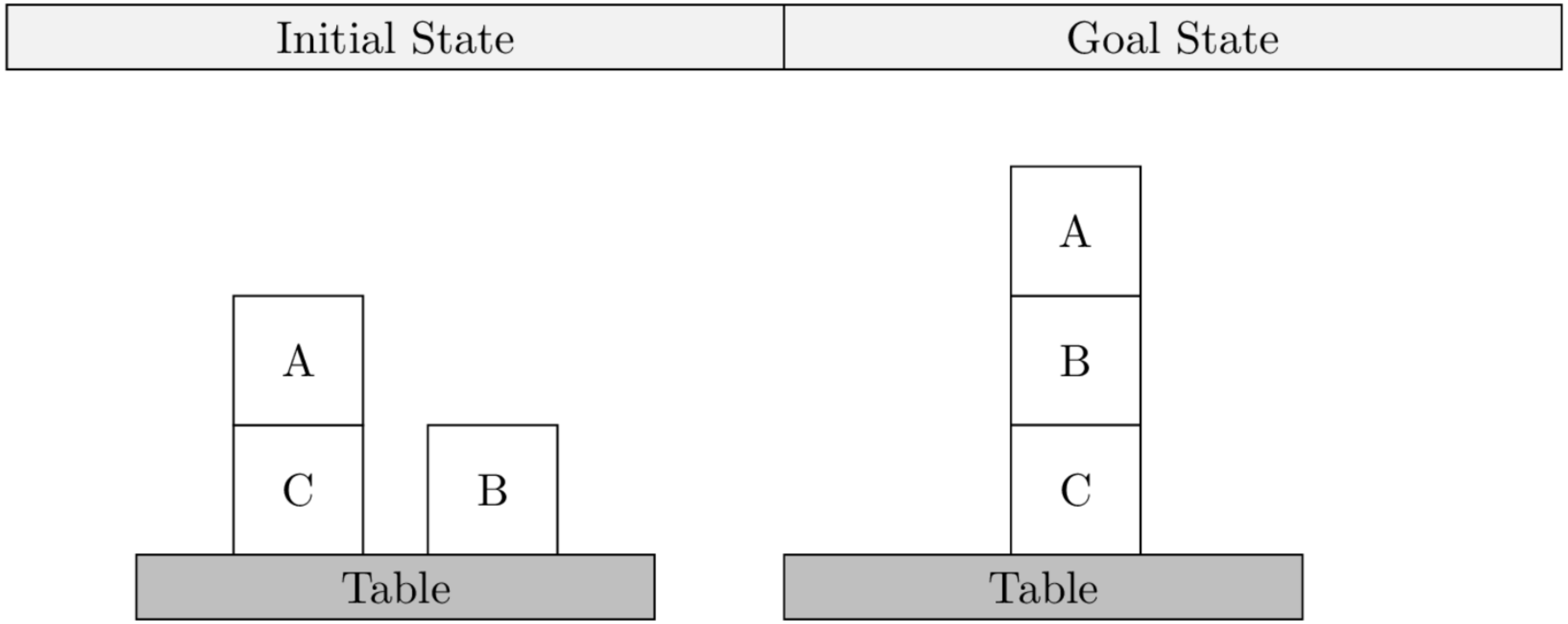
Problem 2

Task 1. Describe the init and goal set.



Task 1

- I:={on(A, C), onTable(C), onTable(B), clear(A), clear(B), armFree}
- G:={on(A, B), on(B, C), onTable(c), clear(A)}



The additive and max heuristics

Definition (h^{add}). *Let* $\Pi = (F, A, c, I, G)$ *be a STRIPS planning task. The additive heuristic* h^{add} *for* Π *is the function* $h^{\text{add}}(s) := h^{\text{add}}(s, G)$ *where* $h^{\text{add}}(s, g)$ *is the point-wise greatest function that satisfies* $h^{\text{add}}(s, g) =$

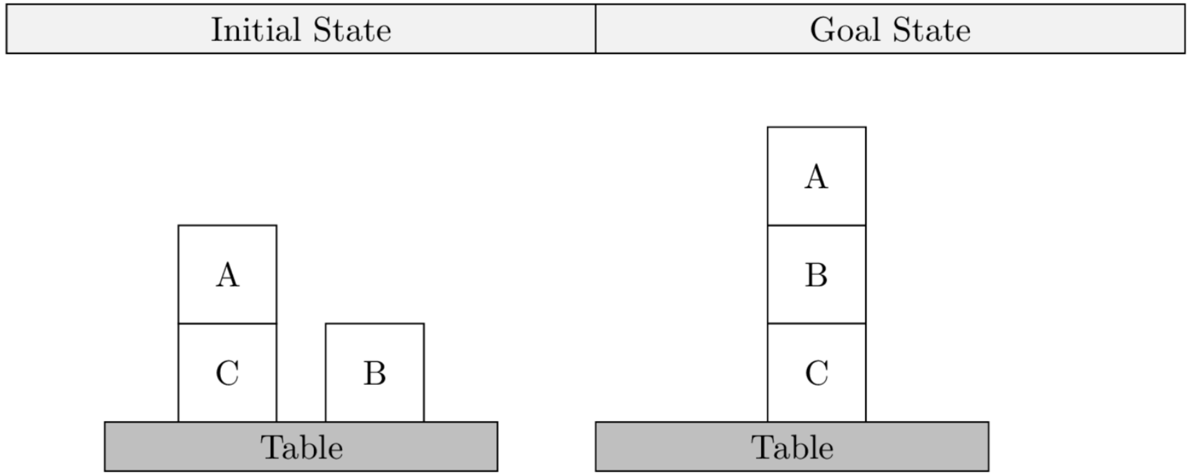
$$\begin{cases} 0 & g \subseteq s \\ min_{a \in A, g \in add_a} c(a) + h^{\text{add}}(s, pre_a) & |g| = 1 \\ \sum_{g' \in g} h^{\text{add}}(s, \{g'\}) & |g| > 1 \end{cases}$$

Definition (h^{max}). *Let* $\Pi = (F, A, c, I, G)$ *be a STRIPS planning task. The max heuristic* h^{max} *for* Π *is the function* $h^{\text{max}}(s) := h^{\text{max}}(s, G)$ *where* $h^{\text{max}}(s, g)$ *is the point-wise greatest function that satisfies* $h^{\text{max}}(s, g) =$

$$\begin{cases} 0 & g \subseteq s \\ min_{a \in A, g \in add_a} c(a) + h^{\text{max}}(s, pre_a) & |g| = 1 \\ \max_{g' \in g} h^{\text{max}}(s, \{g'\}) & |g| > 1 \end{cases}$$

Problem 2

- Task 2. Compute $hadd(s0)$ for the 4 operators blocks-world problem.
- I:={on(A, C), onTable(C), onTable(B), clear(A), clear(B), armFree}
- G:={on(A, B), on(B, C), onTable(c), clear(A)}



Task 2

- I:={on(A, C), onTable(C), onTable(B), clear(A), clear(B), armFree}
- G:={on(A, B), on(B, C), onTable(c), clear(A)}

$hadd(s0)$

= $hadd(s0, \text{G})$

= $hadd(\text{on(A, B), on(B, C), onTable(c)\}, clear(A)})$

= ?

$$h^{\text{add}}(s,g) = \begin{cases} 0 & g \subseteq s \\ min_{a \in A, g \in add_a} c(a) + h^{\text{add}}(s, pre_a) & |g| = 1 \\ \sum_{g' \in g} h^{\text{add}}(s, \{g'\}) & |g| > 1 \end{cases}$$

Task 2

I: {on(A, C), onTable(C), onTable(B), clear(A),clear(B), armFree}

$hadd(s0)$

= $hadd(s0$, G)

= $hadd$(on(A, B), on(B, C), onTable(c)})

= $hadd$(on(A, B)) + $hadd$(on(B, C)) + $hadd$(onTable(c)) + $hadd$(clear(A))

= $hadd$(on(A, B)) + $hadd$(on(B, C)) + ?

$$h^{\mathsf{add}}(s,g) = \begin{cases} 0 & g \subseteq s \\ min_{a \in A, g \in add_a} c(a) + h^{\mathsf{add}}(s, pre_a) & |g| = 1 \\ \sum_{g' \in g} h^{\mathsf{add}}(s, \{g'\}) & |g| > 1 \end{cases}$$

Task 2

I: {on(A, C), onTable(C), onTable(B), clear(A),clear(B), armFree}

$hadd(s0)$

= $hadd(s0, \text{G})$

= $hadd$(on(A, B), on(B, C), onTable(c)})

= $hadd$(on(A, B)) + $hadd$(on(B, C)) + $hadd$(onTable(c)) + $hadd$(clear(A))

= $hadd$(on(A, B)) + $hadd$(on(B, C)) + 0 + 0

$$h^{\text{add}}(s, g) = \begin{cases} 0 & g \subseteq s \\ min_{a \in A, g \in add_a} c(a) + h^{\text{add}}(s, pre_a) & |g| = 1 \\ \sum_{g' \in g} h^{\text{add}}(s, \{g'\}) & |g| > 1 \end{cases}$$

Task 2

$$h^{\mathsf{add}}(s,g) = \begin{cases} 0 & g \subseteq s \\ min_{a \in A, g \in add_a} c(a) + h^{\mathsf{add}}(s, pre_a) & |g| = 1 \\ \sum_{g' \in g} h^{\mathsf{add}}(s, \{g'\}) & |g| > 1 \end{cases}$$

$hadd(s0)$

= $hadd(s0$, G)

= $hadd$(on(A, B), on(B, C), onTable(c)})

= $hadd$(on(A, B)) + $hadd$(on(B, C)) + $hadd$(onTable(c)) + $hadd$(clear(A))

= $hadd$(on(A, B)) + $hadd$(on(B, C)) + 0 + 0

= cost(stack(A, B) + $hadd$(prec(stack(A, B)) + ...

= 1 + $hadd$(holding(A), clear(B)) + ...

= 1 + $hadd$(holding(A)) + $hadd$(clear(B)) + ...

If we use hadd table

(you may find the table in Colab solution)

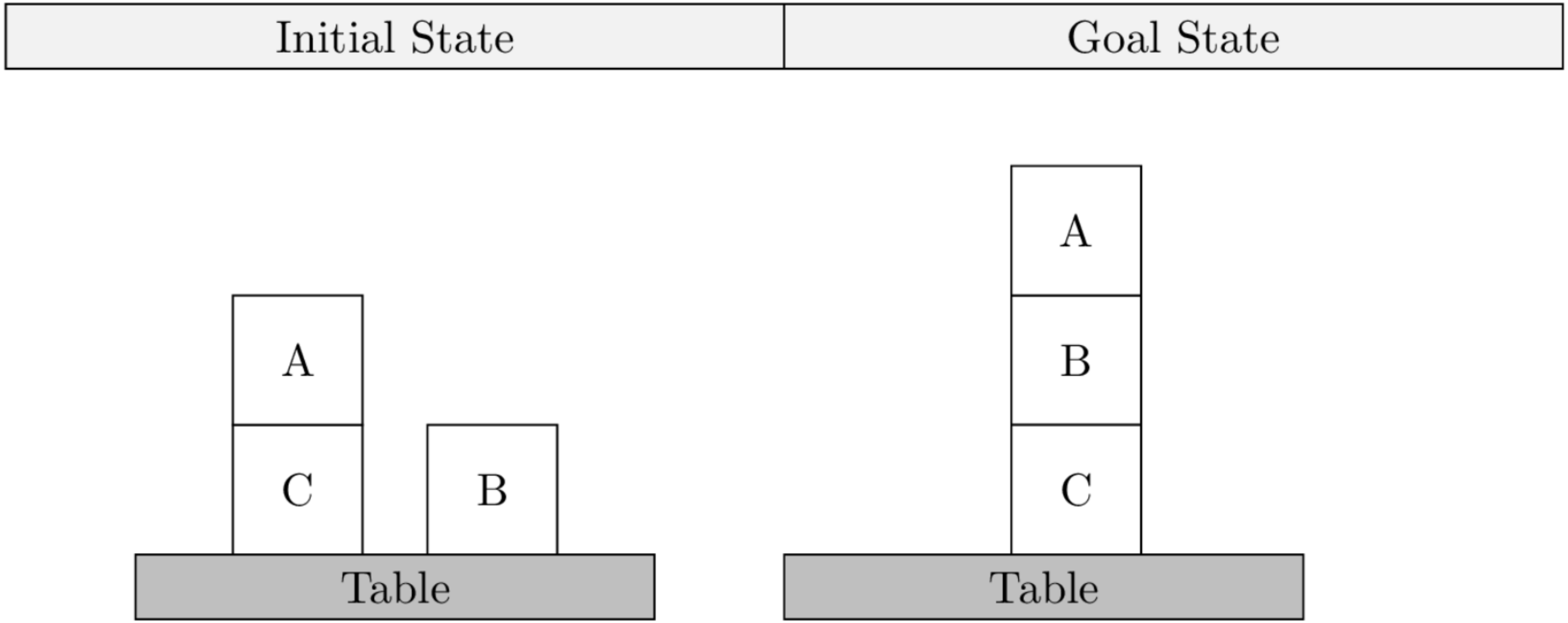
$hadd$(clear (c))

- putdown(c) = 1 + holding (c)
- stack(C, A) = 1 + holding (c) + clear(A)
- stack(C, B) = 1 + holding (c) + clear(B)
- stack(C, C) = 1 + holding (c) + clear(C)
- unstack(A, C) = 1 + armFree + on(A, C) + clear(A) = 1
- unstack(B, C) = 1 + armFree + on(B, C) + clear(B)
- unstack(C, C) = 1 + armFree + on(C, C) + clear(C)

What about on(B, C) in the third row?

Problem 2

- Task 3. Compute $hmax(s0)$ for the 4 operators blocks-world problem.



Consider the following problem: $G = \{A, B, C\}$, $I = \{\}, O = \{add(o_a) = \{A\}, add(o_b) = \{B\}, add(o_c) = \{C\}\}$, which following option is correct?

- $h^* = 3, h_{max} = 1,\ h_{add} = 1$
- $h^* = 3, h_{max} = 1,\ h_{add} = 3$
- $h^* = 3, h_{max} = 3,\ h_{add} = 1$
- $h^* = 3, h_{max} = 3,\ h_{add} = 3$

Consider the following problem: $G = \{A, B, C\}$, $I = \{\}$, $O = \{add(o_a) = \{A, B, C\}\}$, which following option is correct?

- $h^* = 1, h_{max} = 1,\ h_{add} = 1$
- $h^* = 1, h_{max} = 1,\ h_{add} = 3$
- $h^* = 1, h_{max} = 3,\ h_{add} = 1$
- $h^* = 1, h_{max} = 3,\ h_{add} = 3$