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

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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)
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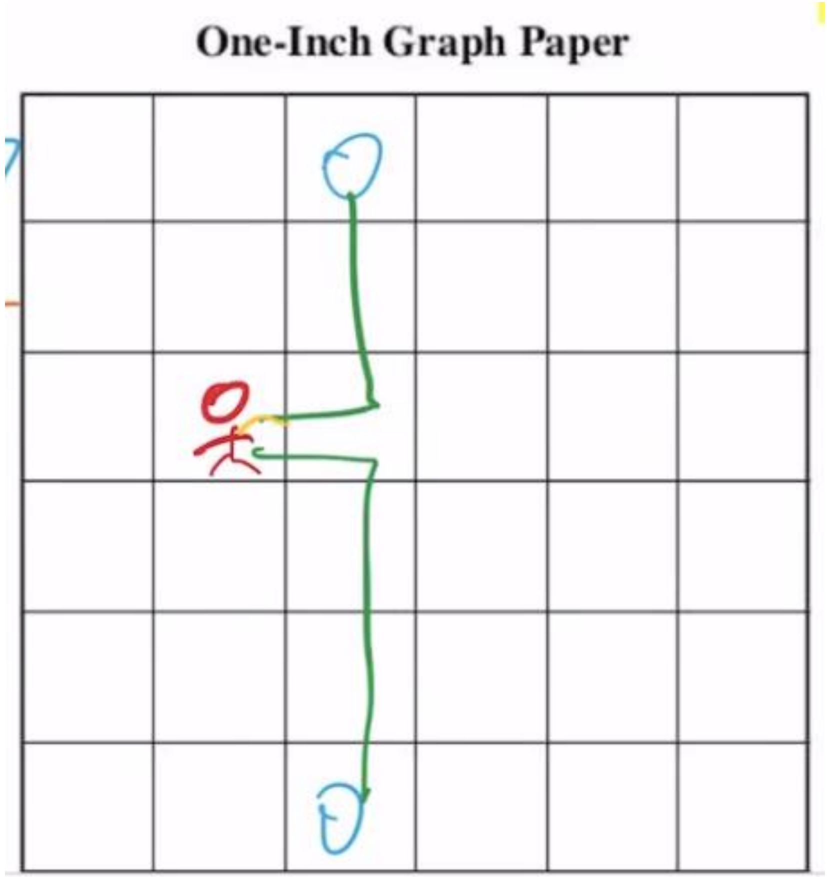
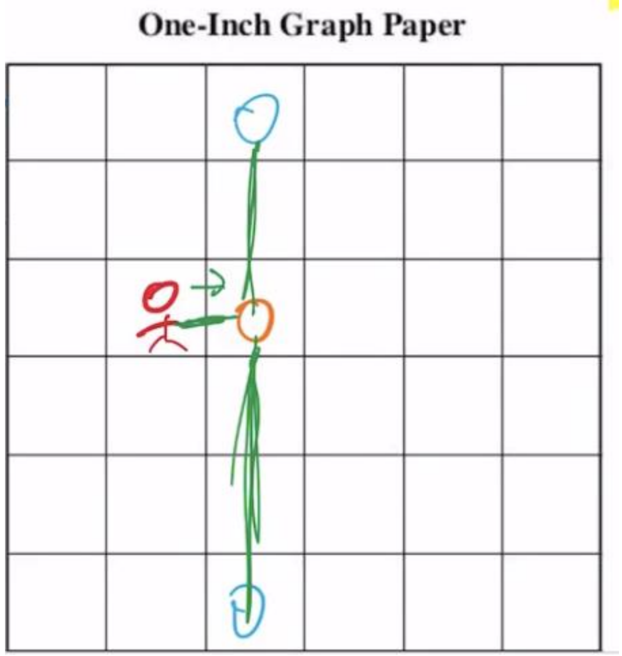
The problem of Minimum Spanning Tree



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?**



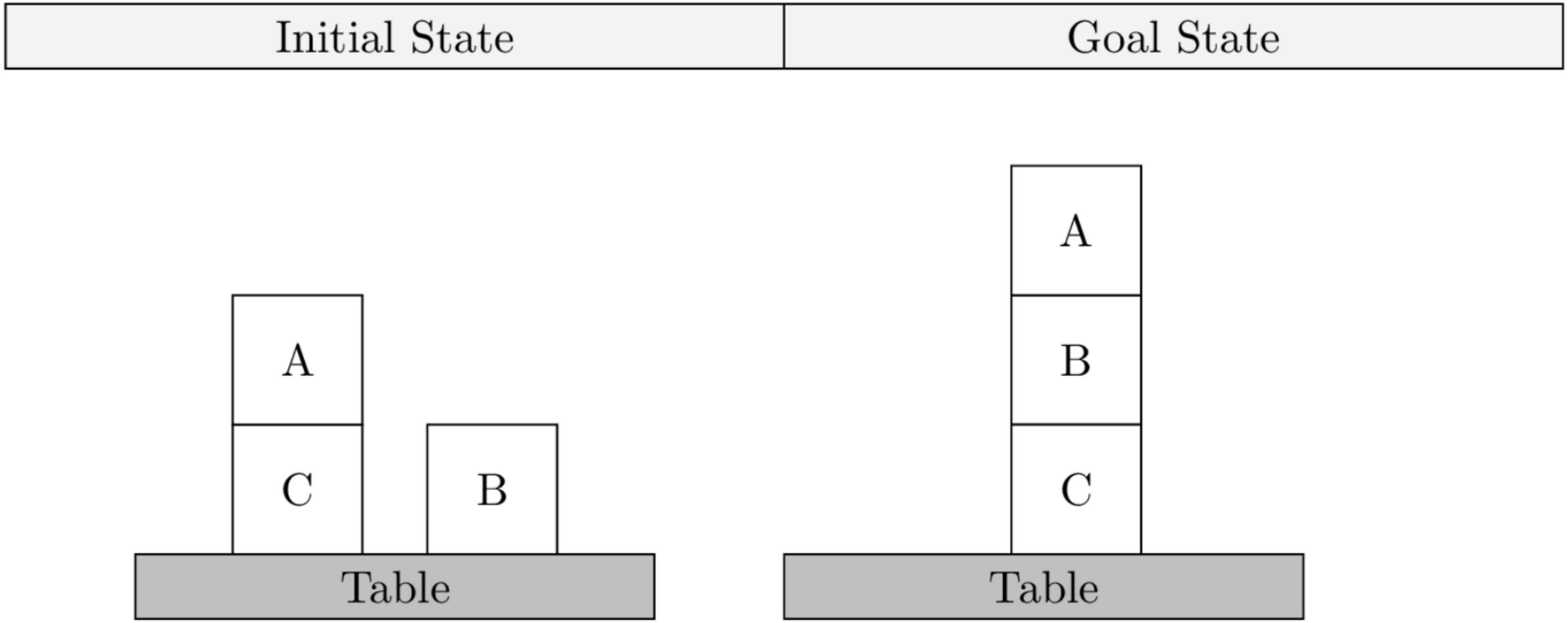
Problem 1

- Discuss in your group the heuristics you used in project 1. Are any of them related to the domain independent heuristics we have covered in class?

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 $h*$?

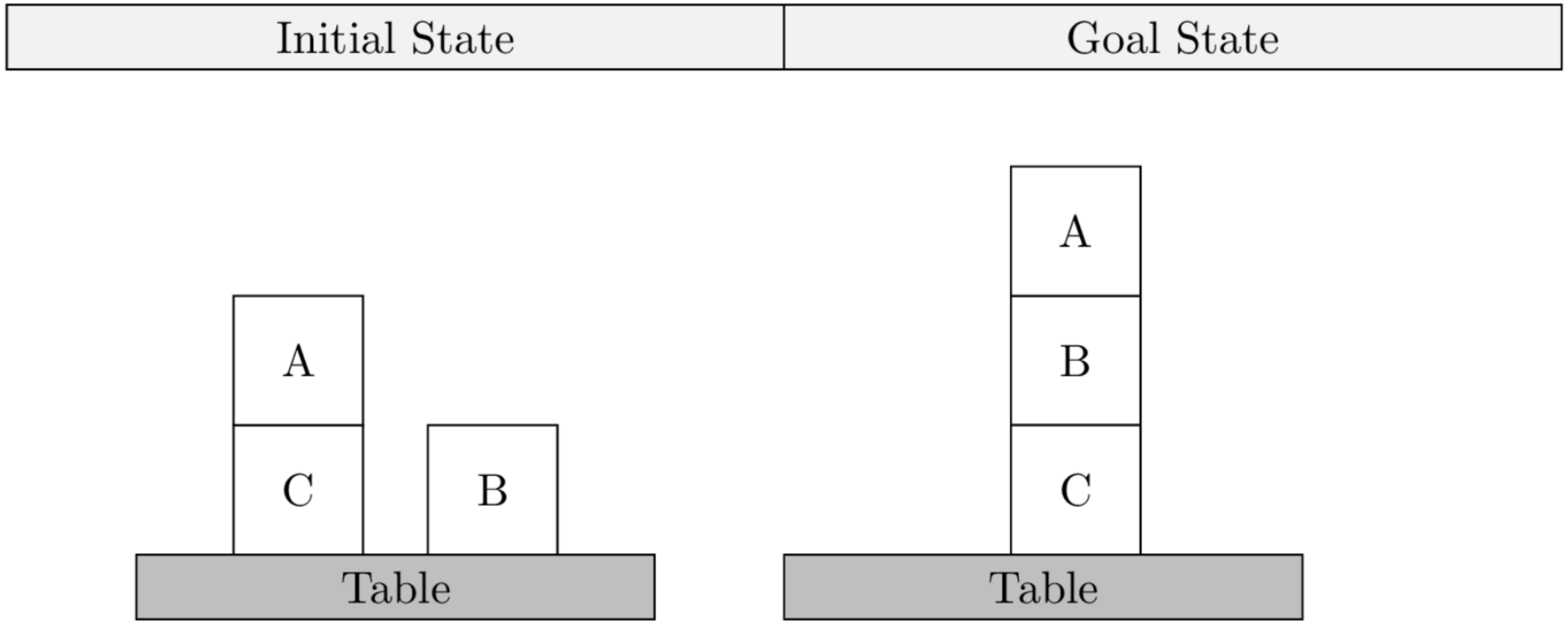
Problem 2

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 $h^{\text{add}}(s, g) =$*

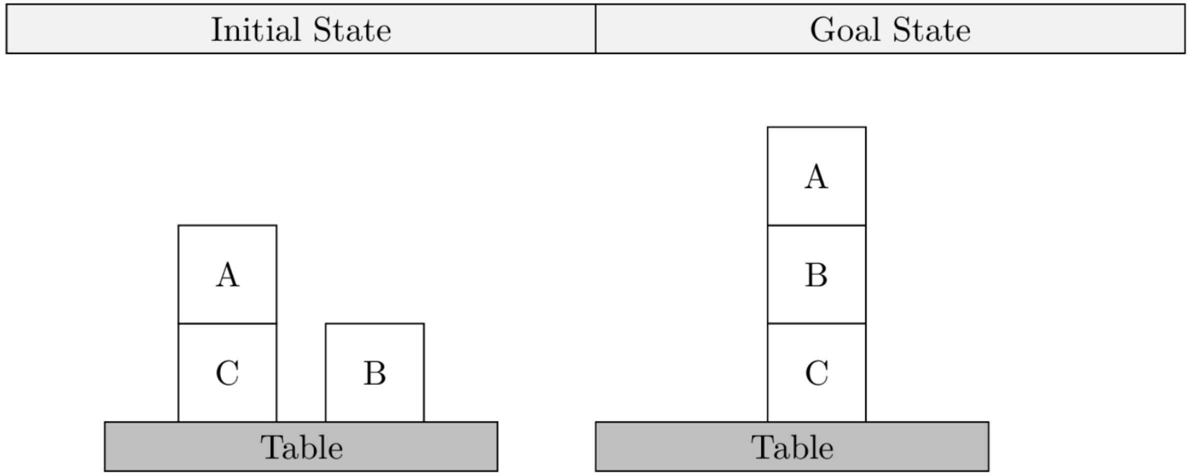
$$\begin{cases} 0 & g \subseteq s \\ min_{a \in A, g \in add_a} c(a) + h^{\text{add}}(s, pre_a) & |g| = 1 \\ \sum_{g' \in g} h^{\text{add}}(s, \{g'\}) & |g| > 1 \end{cases}$$

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 $h^{\max}(s) := h^{\max}(s, G)$ where $h^{\max}(s, g)$ is the point-wise greatest function that satisfies $h^{\max}(s, g) =$*

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

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)}

$hadd(s0)$

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

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

= ?

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

Task 2

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

$hadd(s0)$

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

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

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

= $hadd(\text{on(A, B)}) + hadd(\text{on(B, C)}) +$?

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

Task 2

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

$hadd(s0)$

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

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

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

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

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

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

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

For example

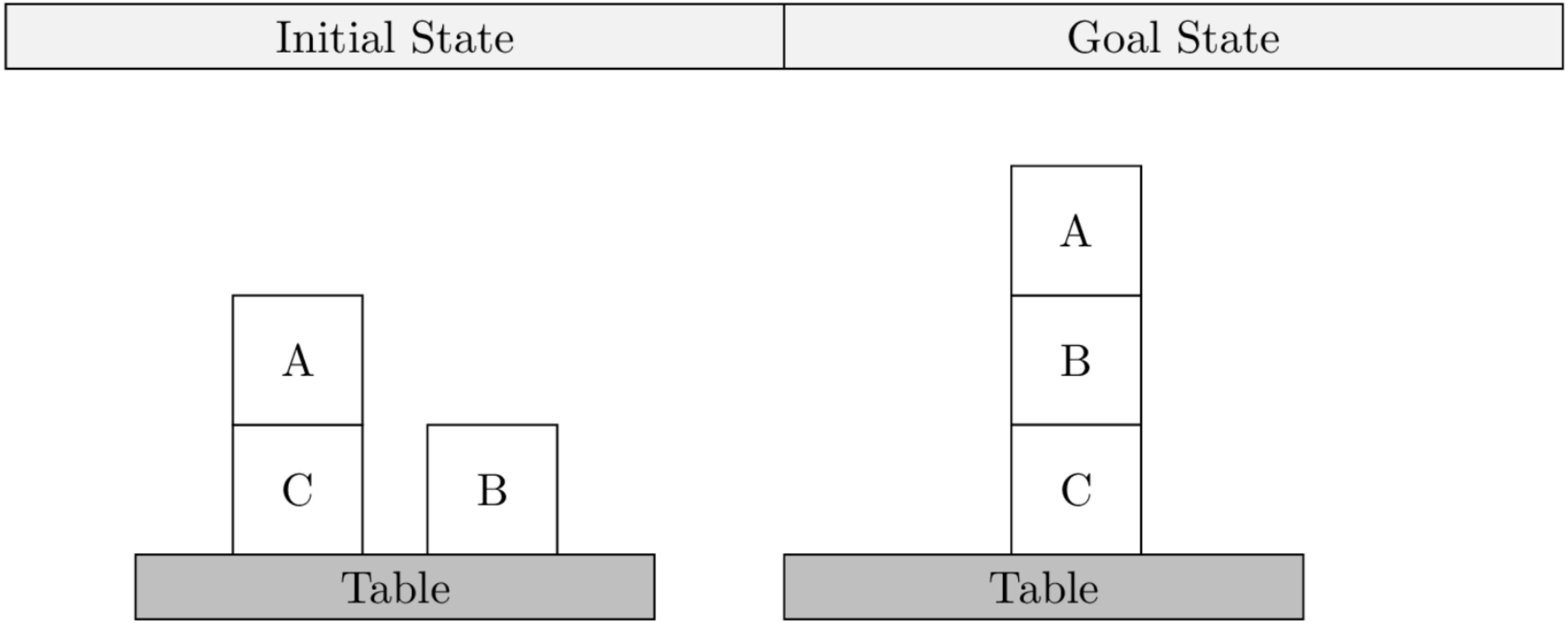
$hadd$(clear (c))

- 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?

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