Workshop 5

Recap: Manhattan 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 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(Manhattan(all food))
- 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 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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- For example:
- Precondition & delete relaxation: Ignore delete and precondition, only keep the add
- Subset sum – still NP-hard problem

Common Heuristic for Manhattan Problems

- Goal counting: $h = |V'|$
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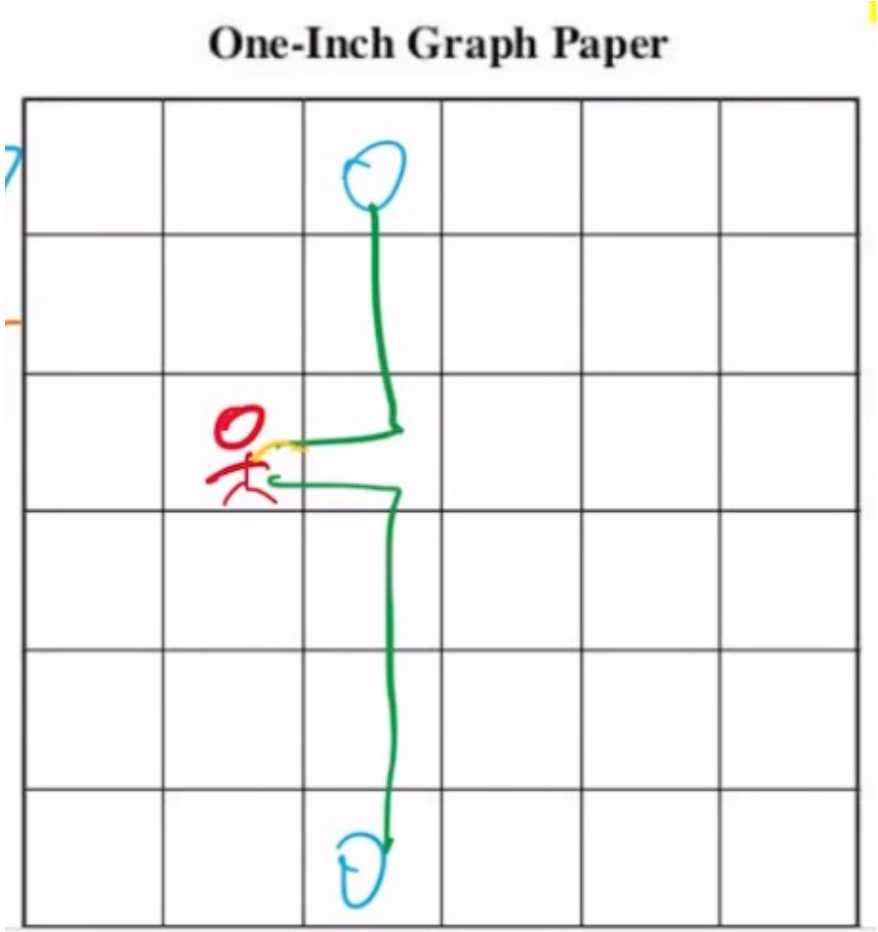
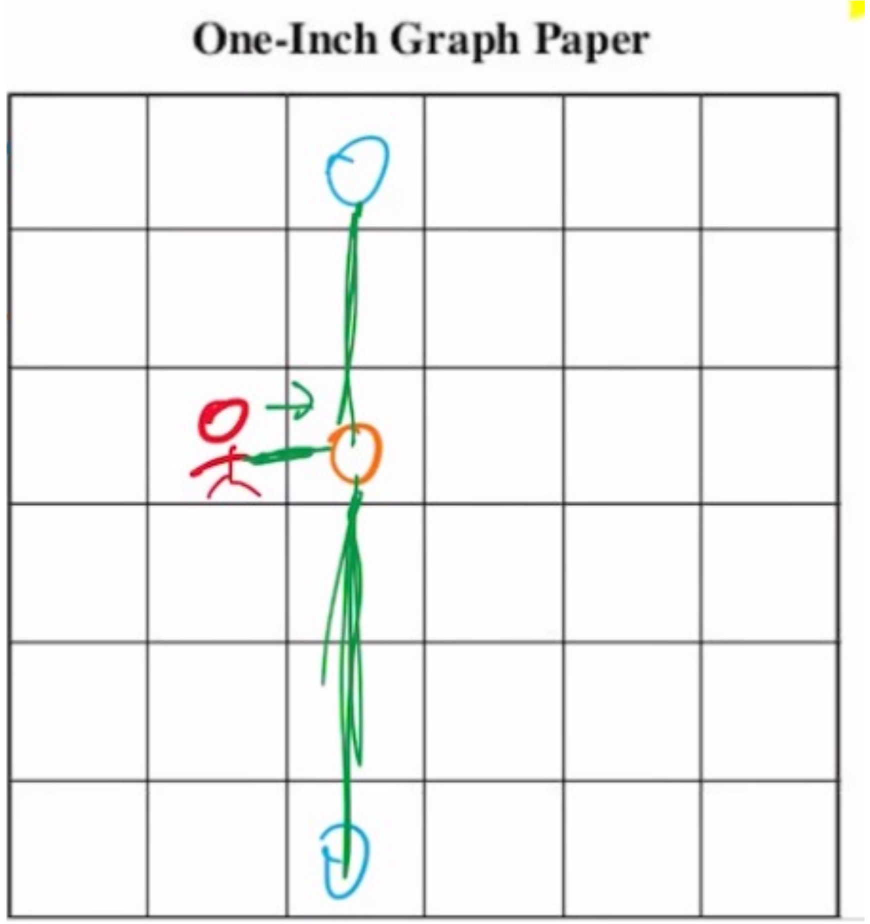
The problem of Minimum Spanning Tree

- Not consistent



Minimum Steiner Tree:

- add extra node, becomes consistent
- How to derive from the original?
- Delete relaxation: h+



Problem 1

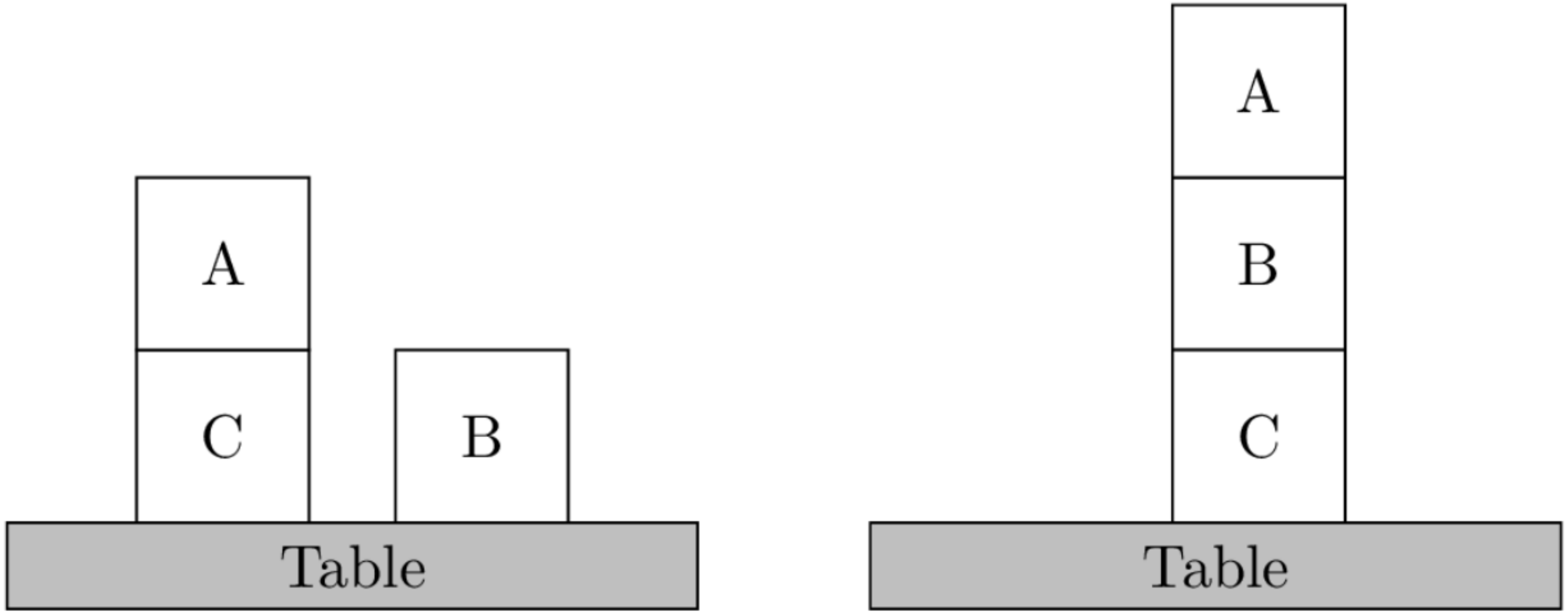
- Discuss in your group the heuristics you used in project 1. Are any of them related to the domain independent heuristics we have covered in class?

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

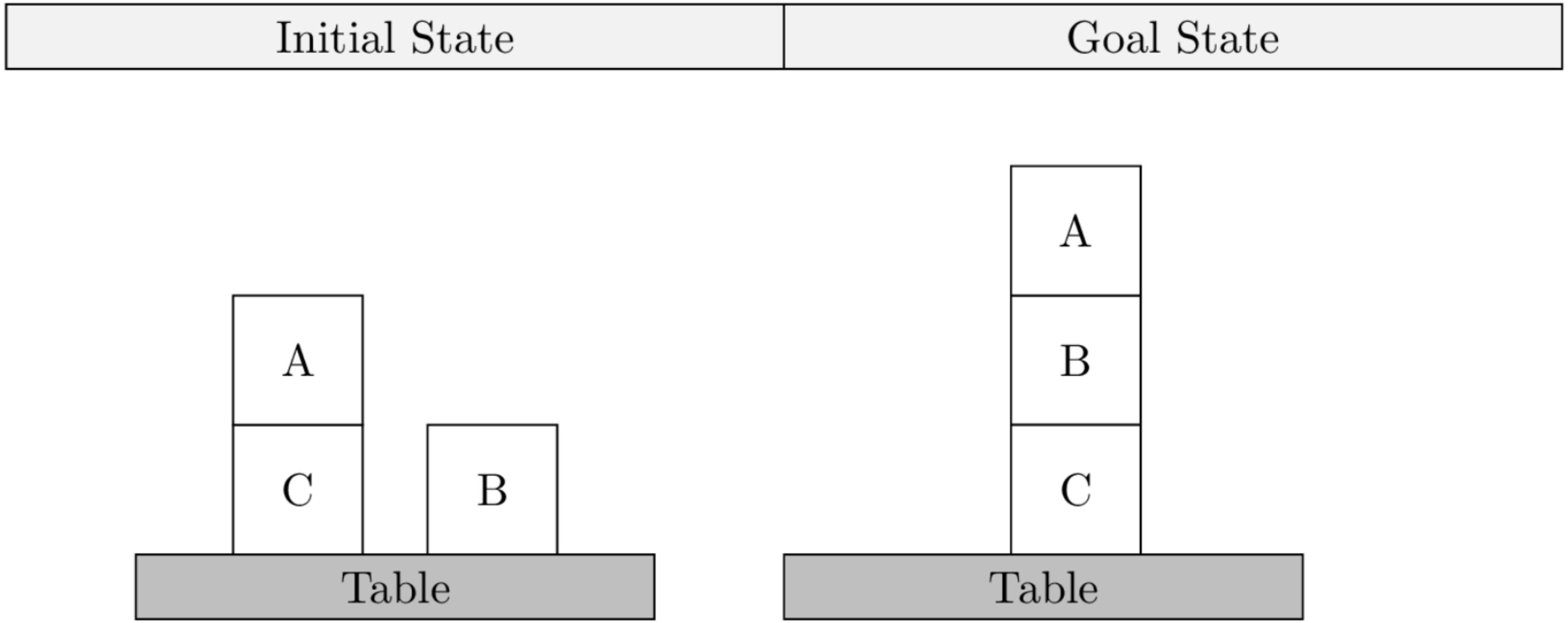
- Task 1. Describe the init and goal set.

Initial State	Goal State



Task 1

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



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

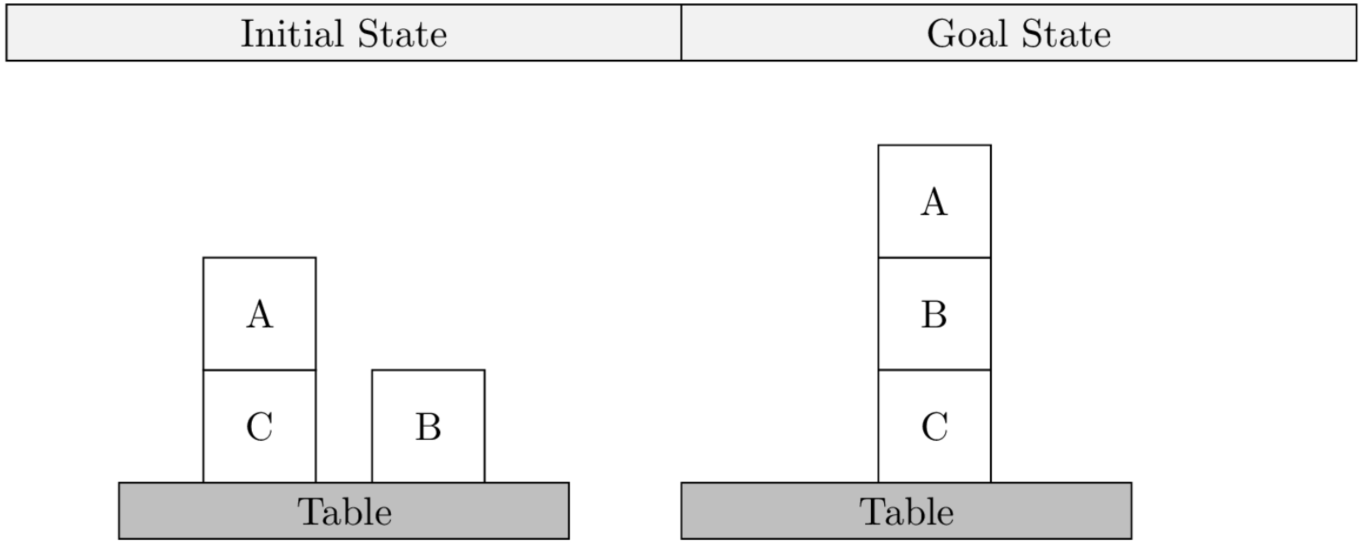
$$\begin{cases} 0 & g \subseteq s \\ min_{a \in A, g \in add_a} c(a) + h^{\text{add}}(s, pre_a) & |g| = 1 \\ \sum_{g' \in g} h^{\text{add}}(s, \{g'\}) & |g| > 1 \end{cases}$$

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)}



Task 2

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

$hadd(s0)$

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

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

$hadd(s0)$

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

= $hadd$(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)) + ?

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

Task 2

$hadd(s0)$

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

= $hadd($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)) $+ \ldots.$

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

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

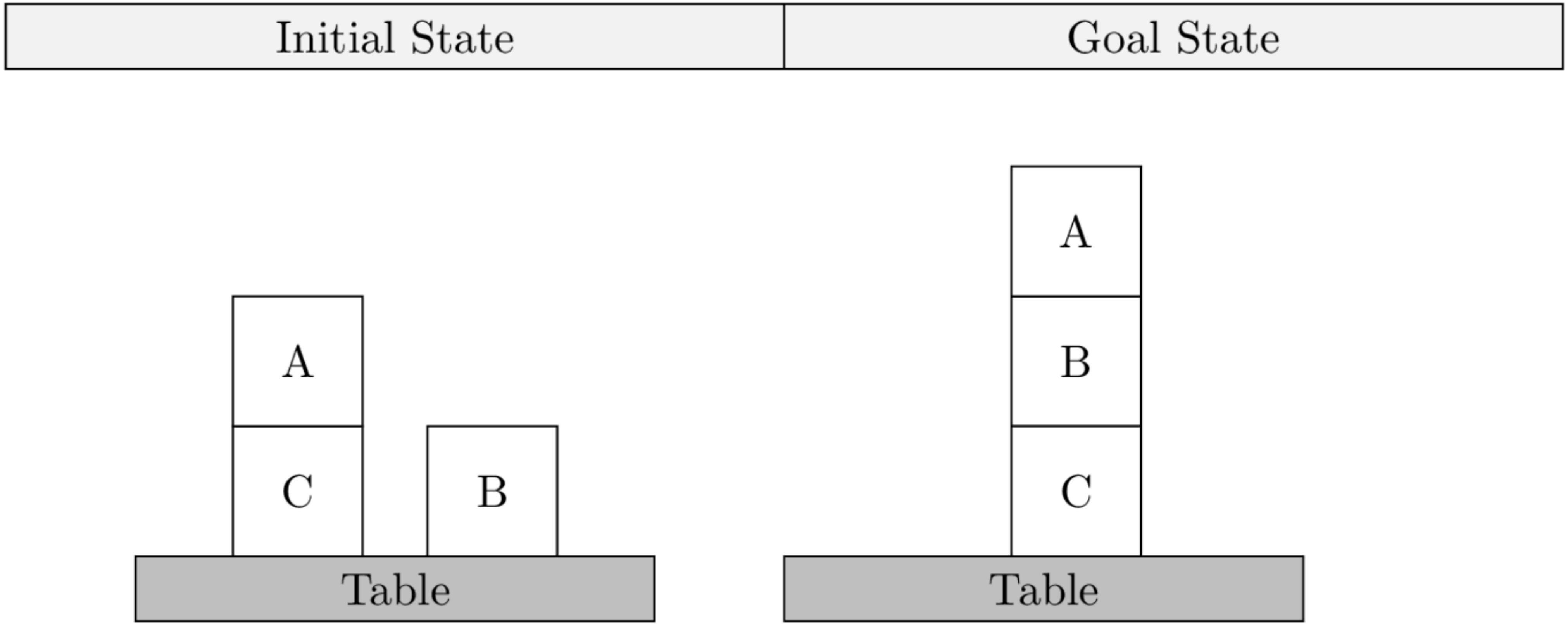
For example

$hadd(\text{clear}(\text{c}))$

- 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?

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