Week 4: STRIPS and Heuristic

COMP90054 – AI Planning for Autonomy

Key concepts

- STRIPS problem
- Heuristic functions

Problem 1

Consider a m x m manhattan grid, and a set of coordinates G′ to visit in any order, and a set of inaccessible coordinates (walls) W

a state = <current coordinate, a set of remaining coordinates>

Initial state $\boldsymbol{s_0 = < (0,0), G' \backslash \{(0,0)\} >}$

Goal state $\boldsymbol{S_G = \{< (x,y), \{\} > \mid x, y \in \{0, \dots, m-1\}\}}$

State $\boldsymbol{S = \{< (x,y), V' > \mid x, y \in \{0, \dots, m-1\} \wedge V' \subseteq G'\}}$

Action A($\boldsymbol{< (x,y), V' >}$**)** $\boldsymbol{= \{(dx, dy) \mid dx, dy \in \{-1, 0, 1\}}$
$\boldsymbol{\wedge\ |dx| + |dy| = 1}$
$\boldsymbol{\wedge\ x + dx, y + dy \in \{0, \dots, m-1\}}$
$\boldsymbol{\wedge\ (x + dx, y + dy) \notin W\}}$

Transition f($\boldsymbol{< (x,y), V' >, (dx, dy)}$**)** $\boldsymbol{=< (x + dx, y + dy),\ V' \backslash \{(x + dx, y + dy)\} >}$

Cost c($\boldsymbol{a}$**) = 1**

State-space model

$P = <S, s_0, S_G, A, T, c>$

S = State space

s_0 = initial state

S_G = goal states

A = actions

T = transition functions

c = costs

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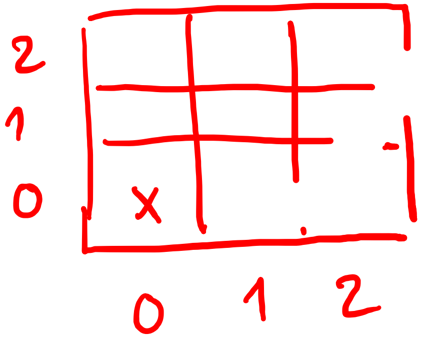
Problem 1

Consider a m x m manhattan grid, and a set of coordinates G′ to visit in any order, and a set of inaccessible coordinates (walls) W



current

$I \;\; = \{at(0,0), visited(0,0)\}$

$G \;\; = \{visited(x, y) | x, y \in G'\}$

$F \;\; = \{at(x, y), visited(x, y) | x, y \in \{0, \dots, m-1\}\}$ → all predicates

- A **problem** in STRIPS is a tuple $P = \langle F, O, I, G \rangle$:
  - F stands for set of all atoms (boolean vars) } (predicates, facts, fluents)
  - O stands for set of all operators (actions)
  - $I \subseteq F$ stands for initial situation
  - $G \subseteq F$ stands for goal situation
- Operators $o \in O$ **represented** by
  - the Add list $Add(o) \subseteq F$ → True
  - the Delete list $Del(o) \subseteq F$ → False
  - the Precondition list $Pre(o) \subseteq F$

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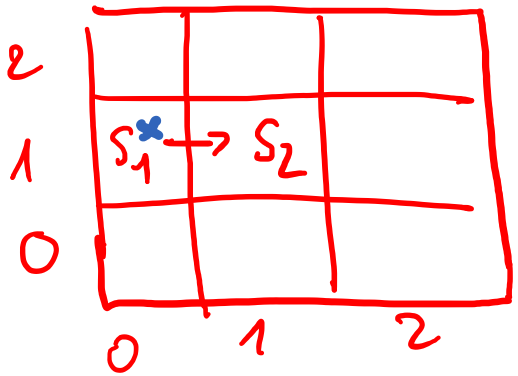
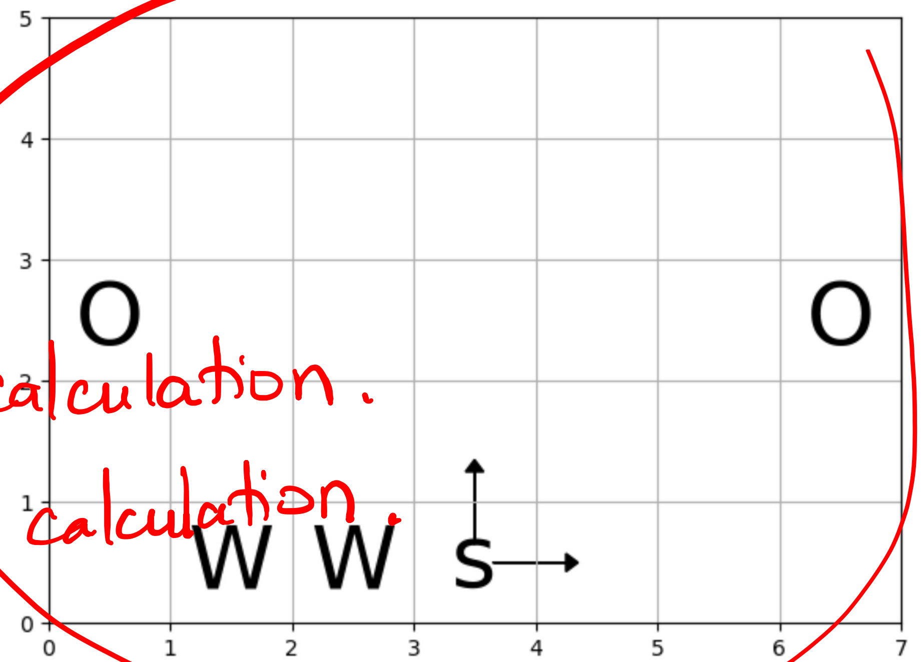
O = {$move(x, y, x', y')$:
- *Prec: at(x,y)*
- *Add: at(x′, y′), visited(x′,y′)*
- *Del: at(x, y) | for each adjacent (x,y),(x′,y′), and (x′,y′) ∉ W* }



– move((0,1), (1,1)):
+ pre: at(0,1)
+ add: at(1,1), visited(1,1)
+ del: at(0,1)

Problem 2

1. Zero heuristic ← Very bad
2. Goal-counting heuristic
3. Manhattan Distance to Closest Goal heuristic
4. Manhattan Distance to Furthest Goal heuristic
5. Sum of manhattan distances of all goals
6. Minimum spanning tree



- Bad heuristic: ↑ search time + ↓ heuristic calculation.
- Good heuristic: ↓ search time + ↑ heuristic calculation.

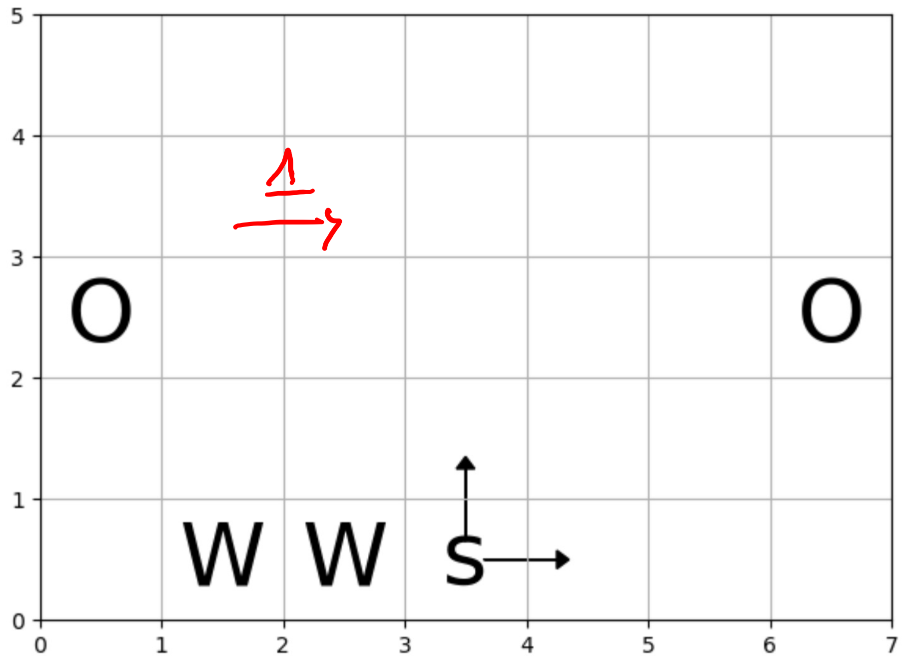
$\underbrace{\text{Number of node expansion}}_{\text{search time}}^{①} + \text{Calculation time of the heuristic function}^{②} = \text{Total running time}$

Tip: If h1 dominates h2 then A with h1 will expand less or equal node to h2* X

Problem 2

1. Zero heuristic h = 0

Admissible: Yes
Consistent: Yes
Time to calculate h: None



parent child

$h(s) - h(s') \leq c(s, s')$

$0 - 0 \leq 1$

$0 < 1$

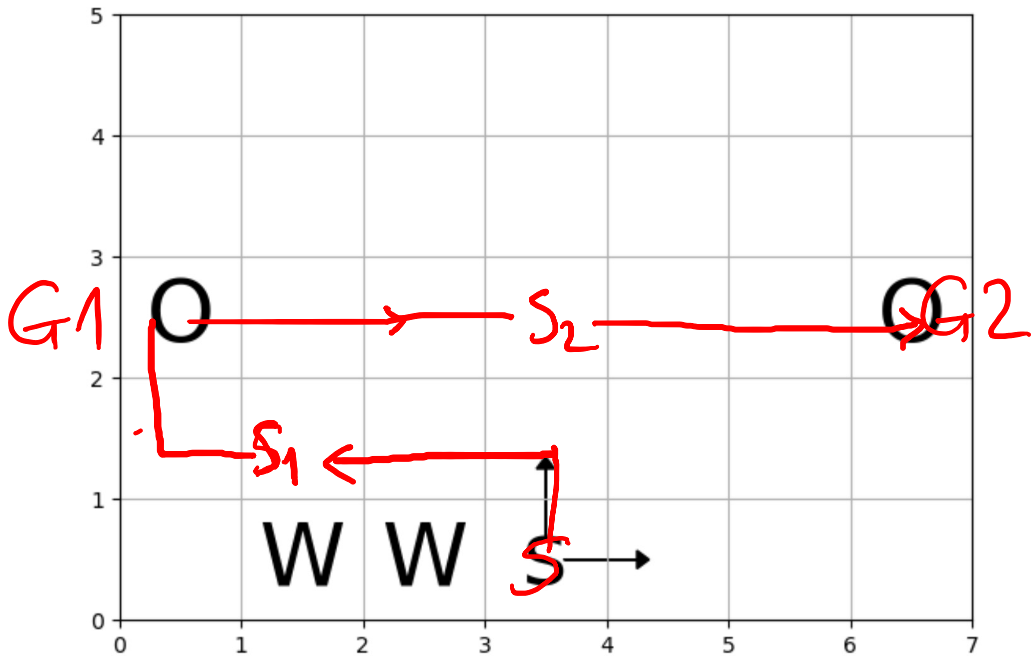
- ? admissible
- ? consistent

$h(s) = 0 \leq h^*(s)$

Problem 2

2. Goal-counting heuristic

Admissible: Yes
Consistent: Yes
Time to calculate h: Easy



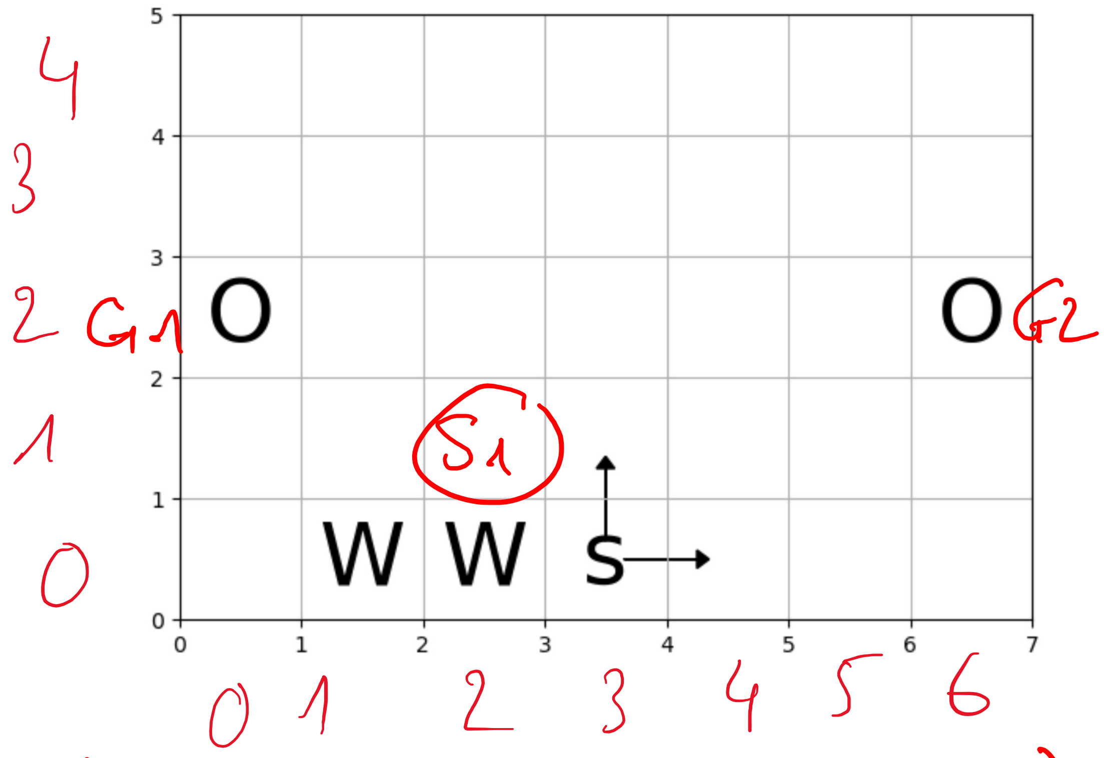
$h(s_1) = 2$

$h(s_2) = 1$

Problem 2

3. Manhattan Distance to Closest Goal heuristic

Admissible: Yes
Consistent: Yes
Time to calculate h: Easy



$$h(s_1) = \min(\underbrace{d(s_1, G1)}, d(s_1, G2))$$
$$= \min(3, 5) = 3$$

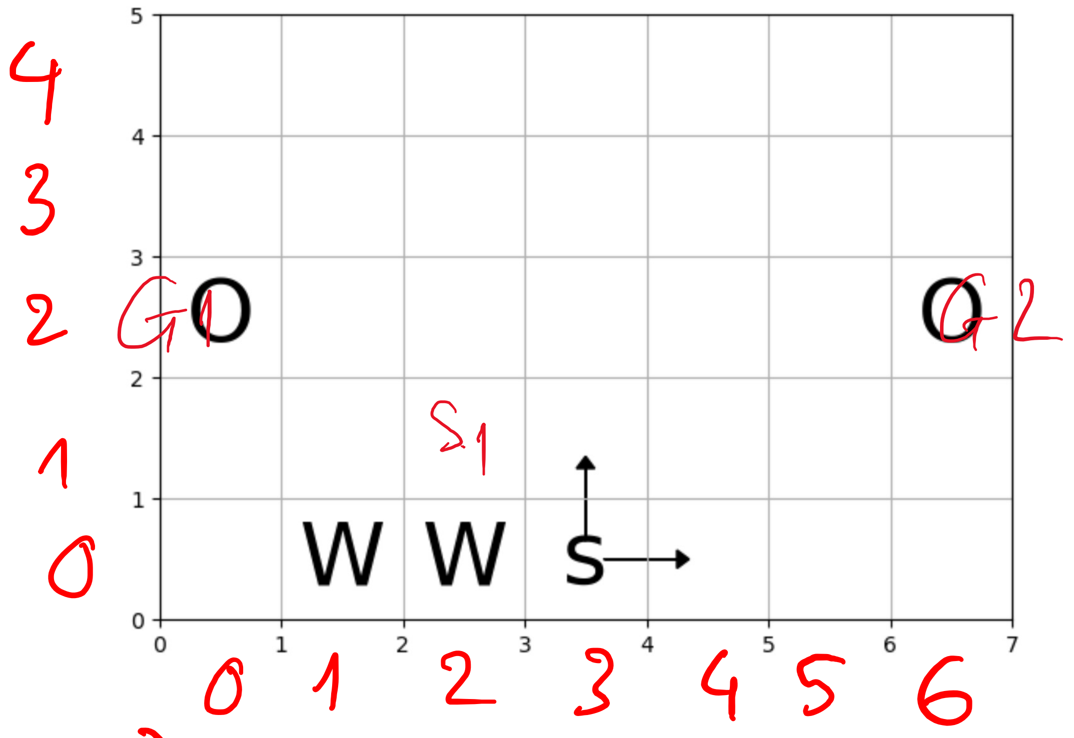
$$d((2,1),(0,2))$$
$$= |2-0| + |1-2|$$
$$= 3$$

$$c(s, s') = 1$$

Problem 2

4. Manhattan Distance to Furthest Goal heuristic

Admissible: Yes
Consistent: Yes
Time to calculate h: Easy

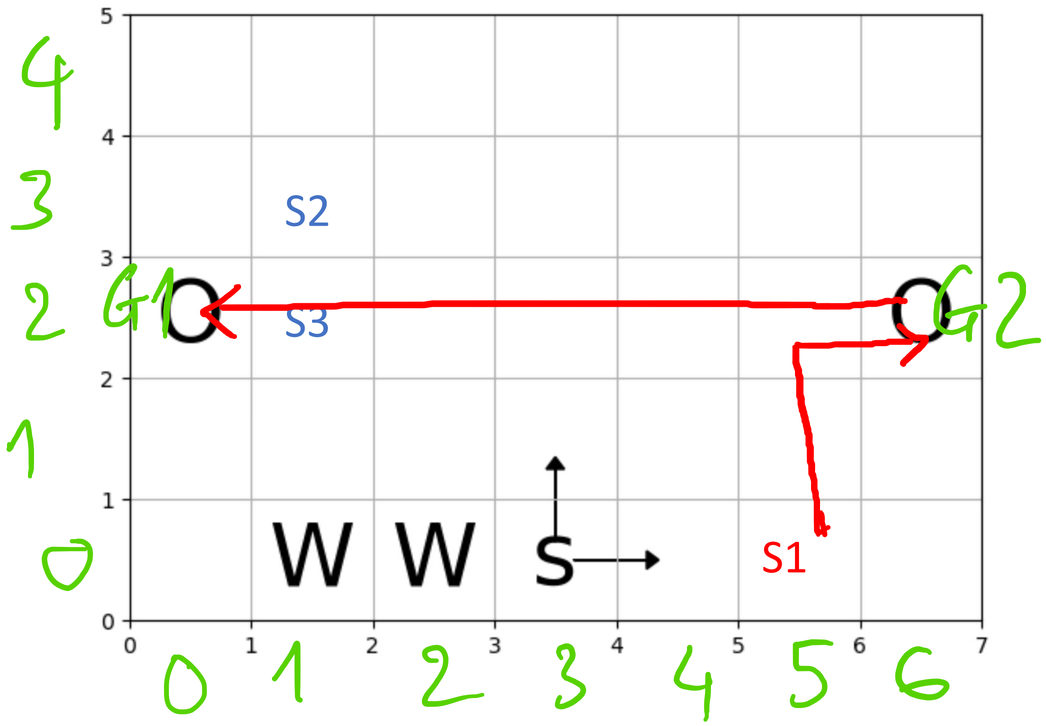


$$h(s_1) = \max\left(d(s_1, G1),\ d(s_1, G2)\right)$$
$$= \max(3,\ 5) = 5$$

Problem 2

5. Sum of Manhattan distances of all goals

Admissible: No
Consistent: No
Time to calculate h: Easy



$h(s_1) = d(s_1, G1) + d(s_1, G2) = 7 + 3 = 10$

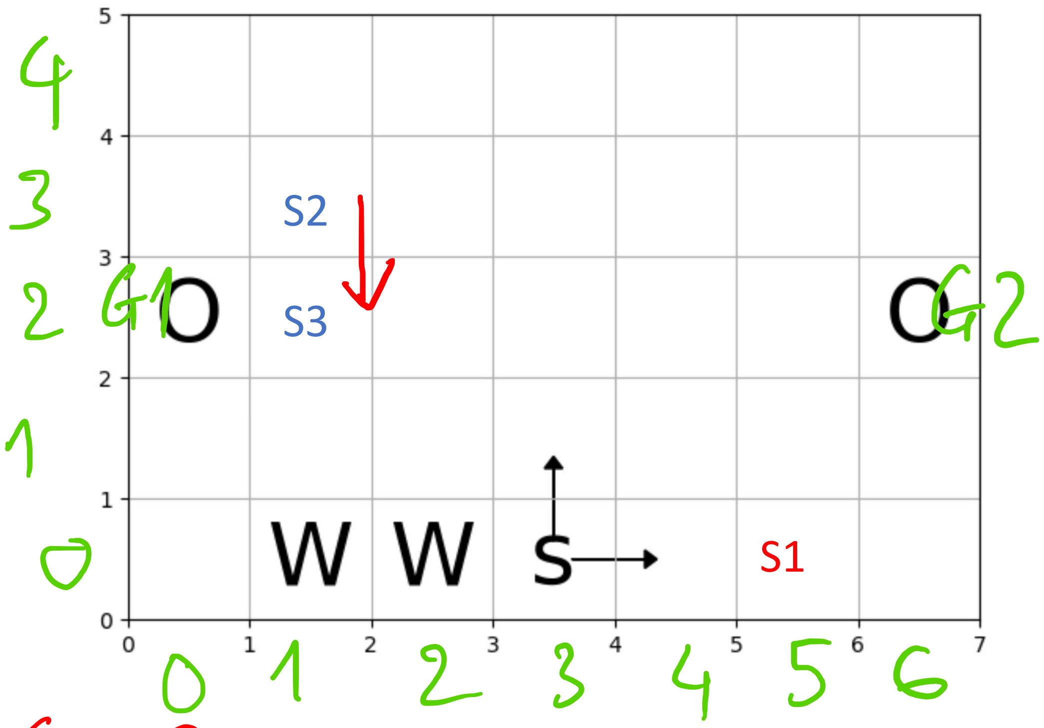
$h^*(s_1) = d(s_1, G2) + d(G1, G2) = 3 + 6 = 9$

$h(s_1) > h^*(s_1) \Rightarrow$ not admissible

Problem 2

5. Sum of Manhattan distances of all goals

Admissible: No
Consistent: No
Time to calculate h: Easy



$h(s_2) = d(s_2, G1) + d(s_2, G2) = 2 + 6 = 8$

$h(s_3) = d(s_3, G1) + d(s_3, G2) = 1 + 5 = 6$

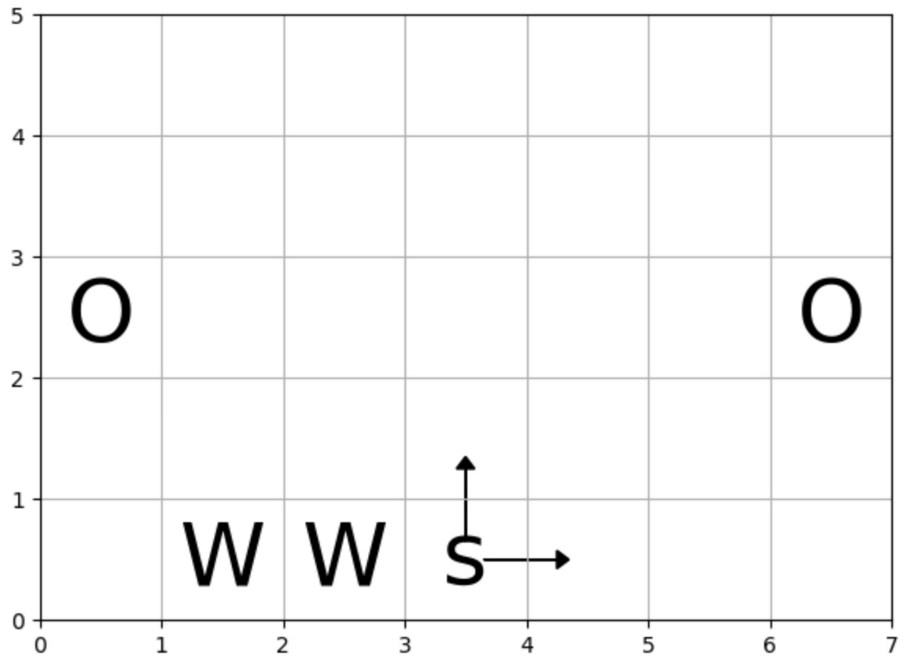
$h(s_2) - h(s_3) = 8 - 6 = 2 > \underbrace{c(s_2, s_3)}_{=1}$

$\Rightarrow$ not consistent.

Problem 2

Dominate relation

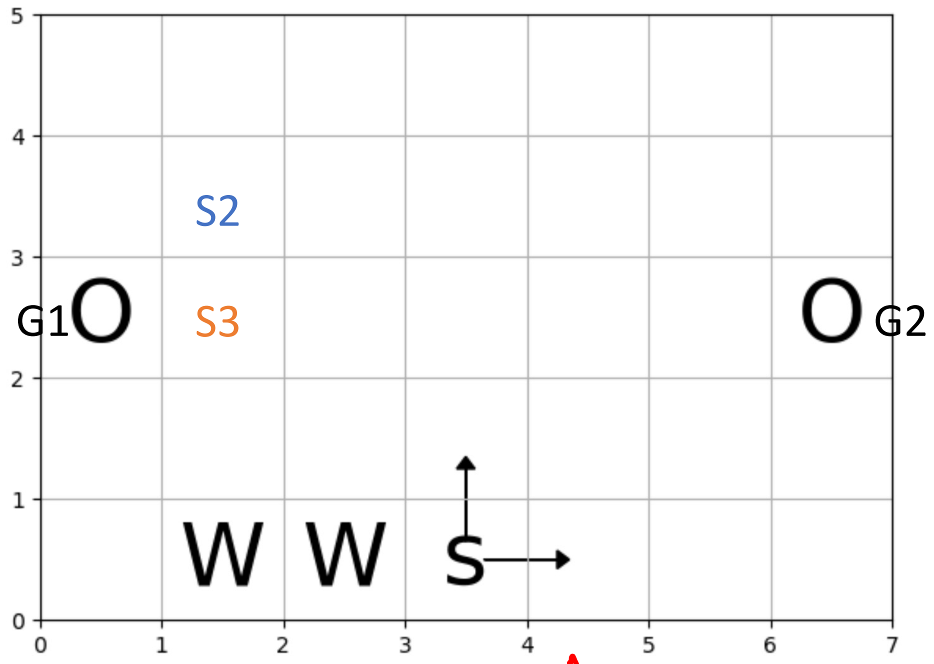
1. Zero heuristic: Admissible, Consistent
2. Goal-counting heuristic: Admissible, Consistent
3. Manhattan Distance to Closest Goal heuristic: Admissible, Consistent
4. Manhattan Distance to Furthest Goal heuristic: Admissible, Consistent
5. ~~Sum of manhattan distances of all goals: Not admissible, Not consistent~~



h(goal counting) > h(zero)
h(closest) > h(zero)
h(furthest) > h(zero)

h(furthest) > h(closest)
h(furthest) > h(goal counting)

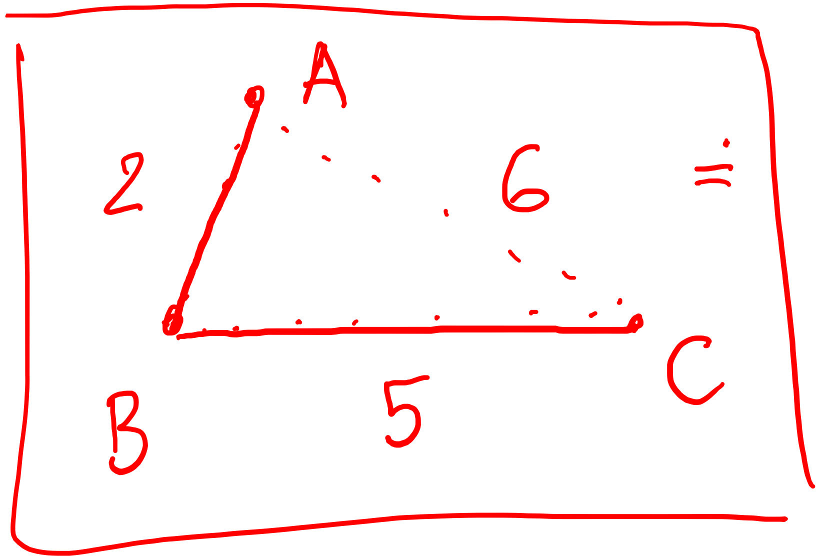
Problem 2



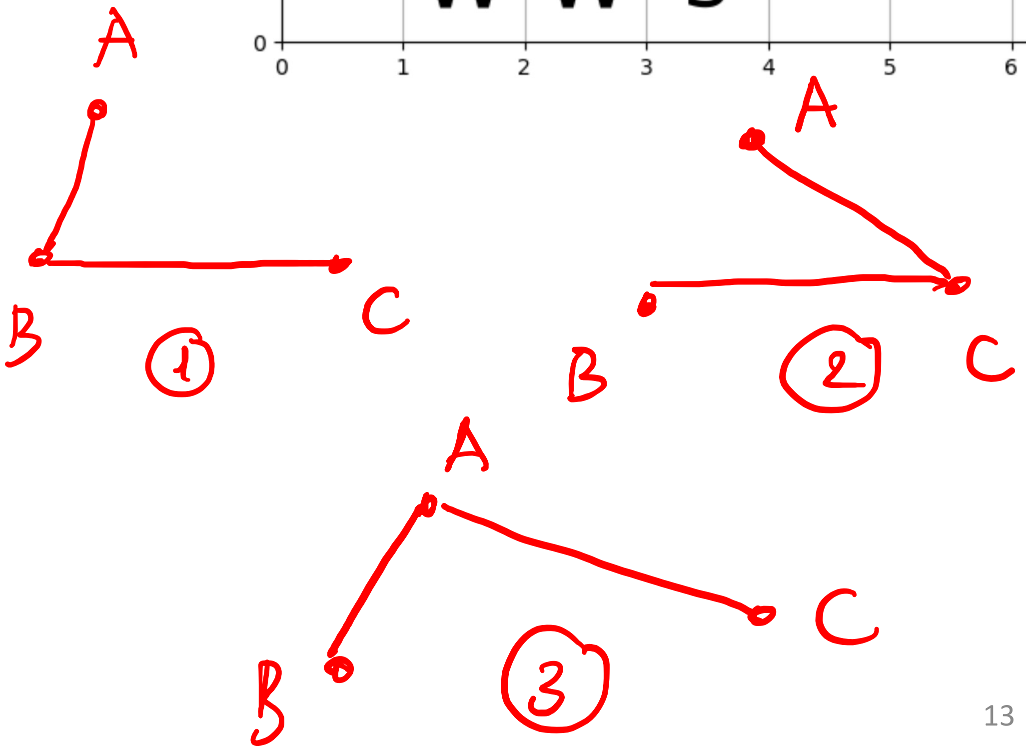
6. Minimum spanning tree

Admissible: Yes
Consistent: No
Time to calculate h: Medium

Minimum spanning tree: Only select a subset of edges to connect all vertices and the total cost is minimum



Cost = 7

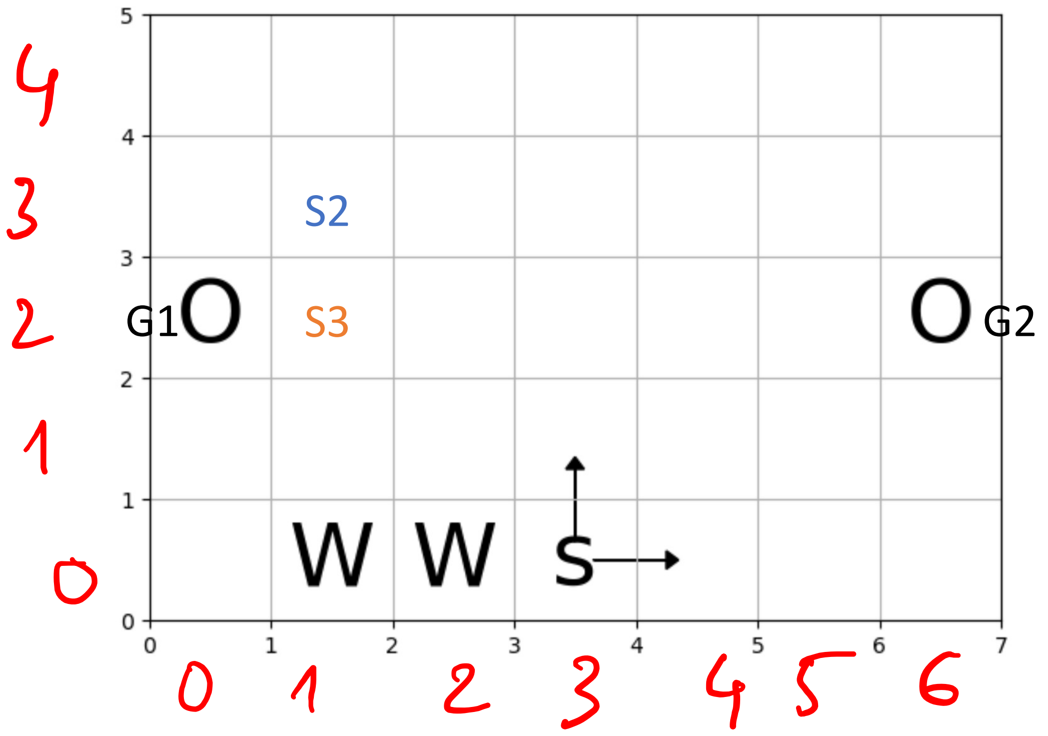


Problem 2

6. Minimum spanning tree

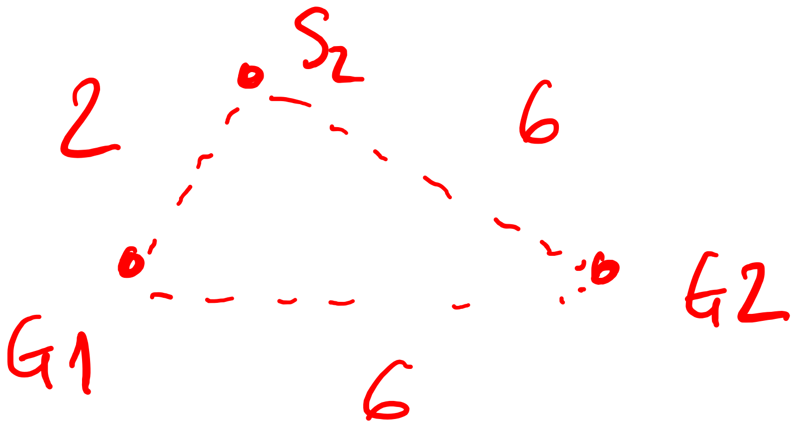
Admissible: Yes
Consistent: No
Time to calculate h: Medium

Minimum spanning tree: Only select a subset of edges to connect all vertices and the total cost is minimum



$h(s_2) = ?$

$h(s_2) = 2+6=8$



$h(s_3) = ?$

$h(s_3) = 6$
$(1+5)$