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>

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

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

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

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

Action A($<(\boldsymbol{x},\boldsymbol{y}), \boldsymbol{V'}>$**)** $= \{(\boldsymbol{dx},\boldsymbol{dy}) \mid \boldsymbol{dx},\boldsymbol{dy} \in \{-\mathbf{1},\mathbf{0},\mathbf{1}\}$

$\wedge\ |\boldsymbol{dx}| + |\boldsymbol{dy}| = \mathbf{1}$

$\wedge\ \boldsymbol{x}+\boldsymbol{dx}, \boldsymbol{y}+\boldsymbol{dy} \in \{\mathbf{0},\dots,\boldsymbol{m}-\mathbf{1}\}$

$\wedge\ (\boldsymbol{x}+\boldsymbol{dx}, \boldsymbol{y}+\boldsymbol{dy}) \notin \boldsymbol{W}\}$

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

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

Problem 1

a state = < curr coordinates, visited coords >

Consider a m x m manhattan grid, and $\boxed{\text{a set of coordinates } G'}$ to visit in any order, and a set of inaccessible coordinates (walls) W

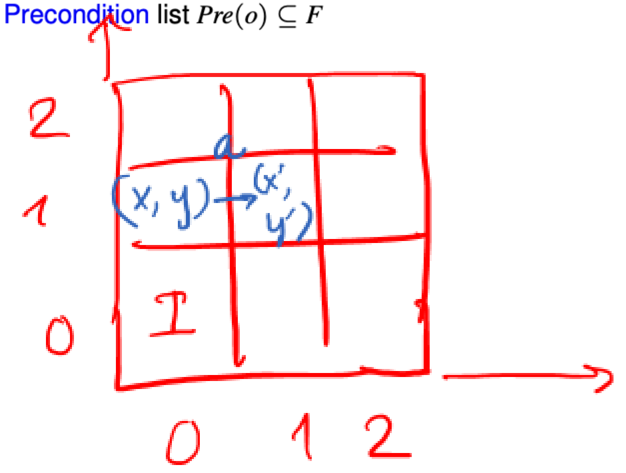
F = { at(x,y), visited(x,y) }

- A **problem** in STRIPS is a tuple $P = \langle F, O, I, G \rangle$:
  - F stands for set of all atoms (boolean vars) facts / predicates / 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 $Add(o) \subseteq F$
  - the Delete list $Del(o) \subseteq F$
  - the Precondition list $Pre(o) \subseteq F$

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

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

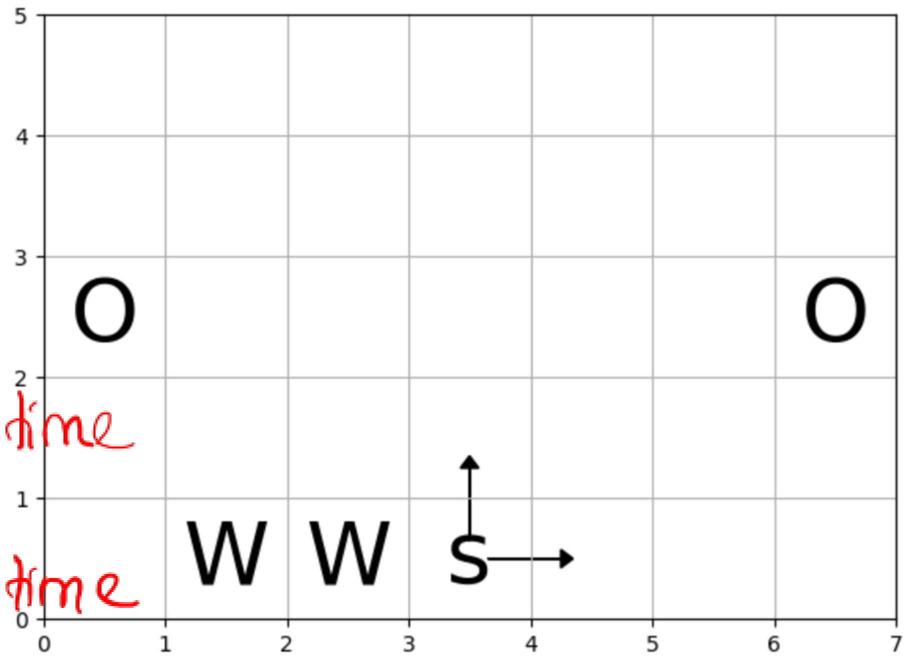
$$F = \{at(x,y), visited(x,y) | x, y \in \{0, \dots, m-1\}\}$$



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

Problem 2

1. $\boxed{\text{Zero heuristic}}$ h=0 (bad)
2. Goal-counting heuristic
3. Manhattan Distance to the Closest Goal heuristic
4. Manhattan Distance to the Farthest Goal heuristic
5. Sum of manhattan distances of all goals
6. Minimum spanning tree



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

Number of node expansion + Calculation time of the heuristic function = Total running time

(search time) (heuristic time).

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

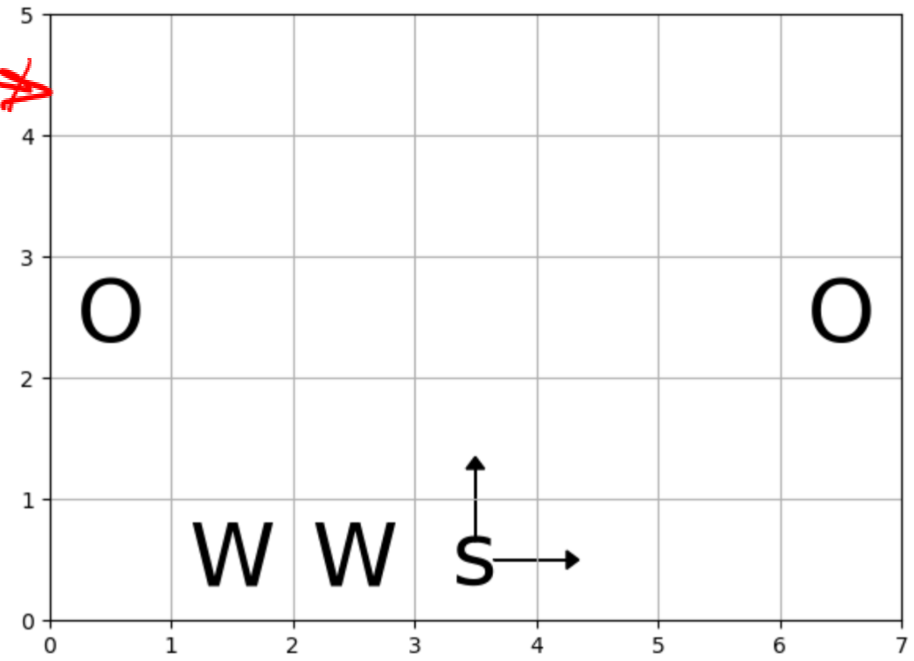
Problem 2

1. Zero heuristic h = 0 (very bad)

↳ blind search

(this map)

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



$$h(s) - h(s') \leq c(s, s')$$
$$0 < 1$$

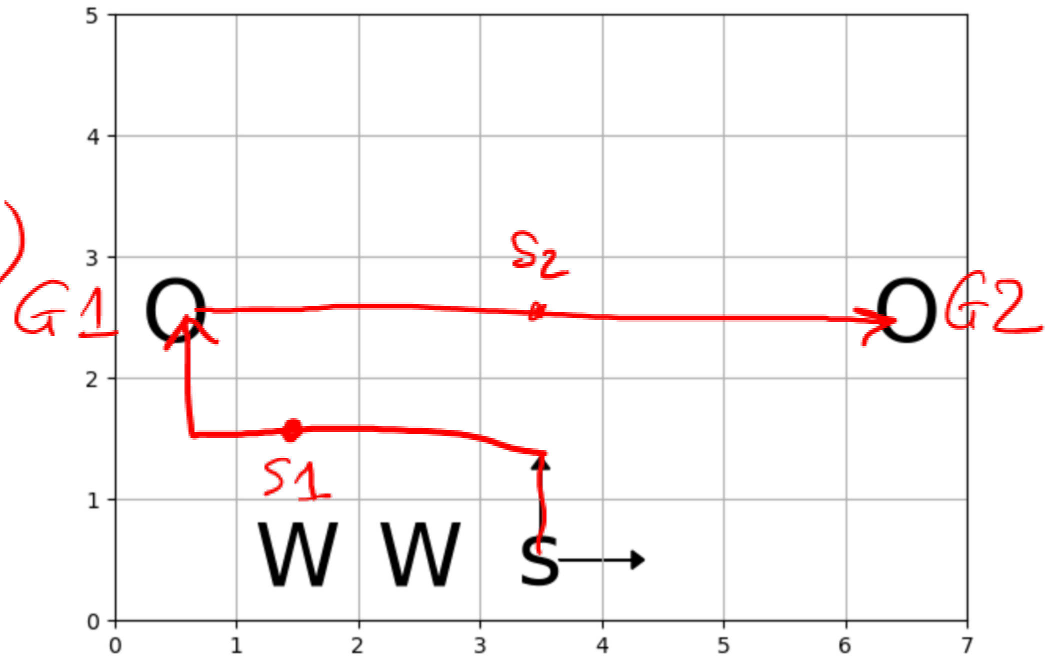
Problem 2

$$h(s) \le h^*(s)$$

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

2. Goal-counting heuristic

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



$$h(s_1) = 2$$

$$h(s_2) = 1$$

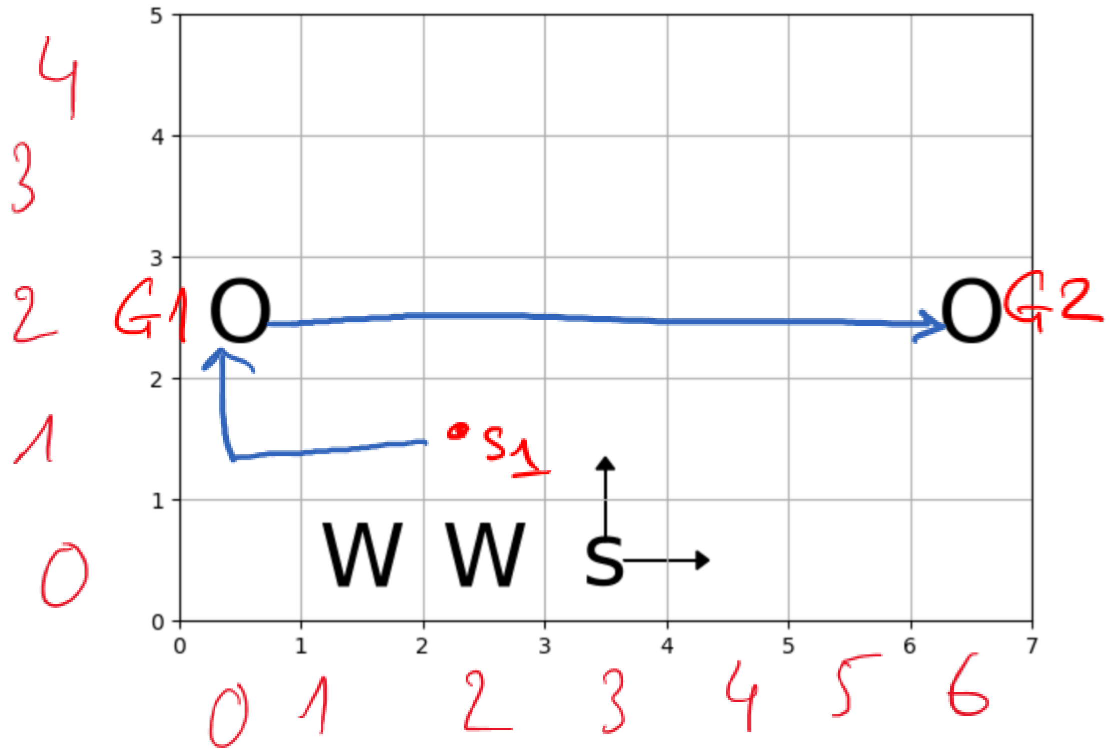
Problem 2

3. Manhattan Distance to the Closest Goal heuristic

Admissible: Yes

Consistent: Yes

Time to calculate h: Easy



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

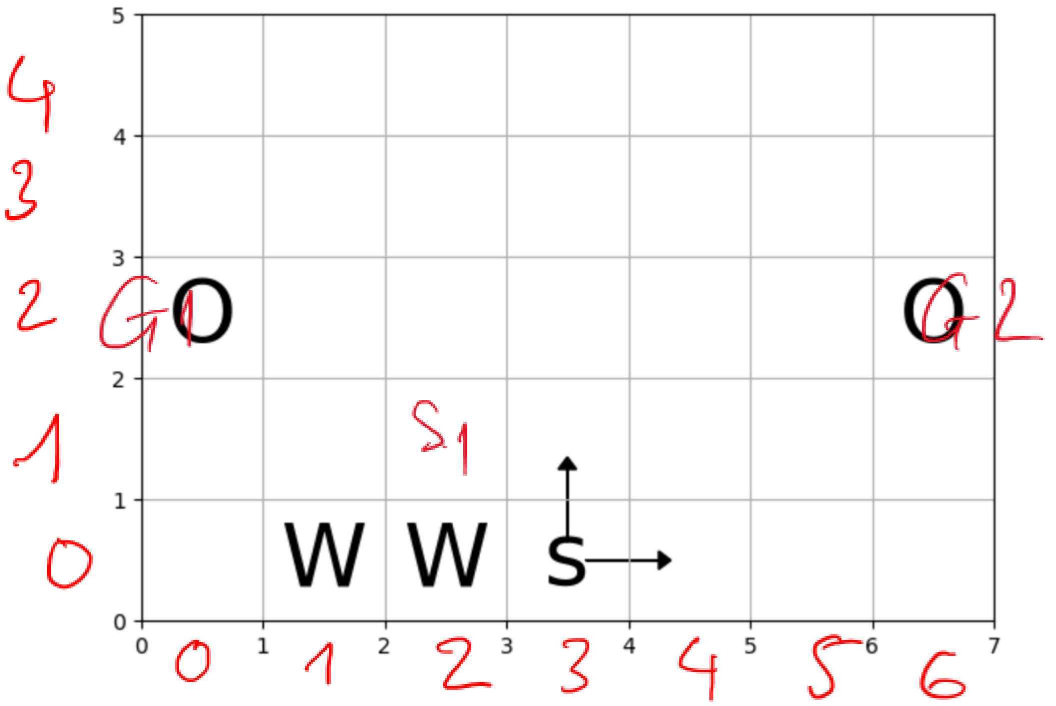
$$h(s_1) = \min(d(s_1, G1), d(s_1, G2))$$
$$= \min(3, 5)$$
$$= 3$$

Problem 2

4. Manhattan Distance to the Farthest Goal heuristic

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

$h^*(s_1) = ?$



$h(s_1) = \max(d(s_1, G_1), d(s_1, G_2))$

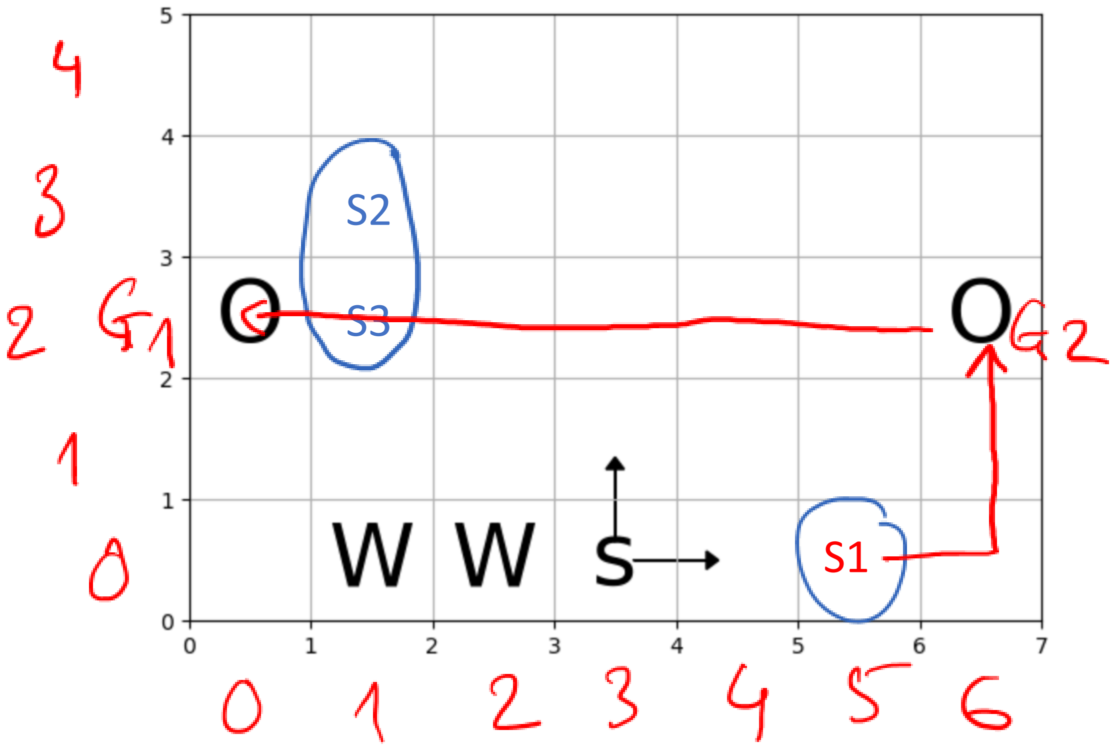
$= \max(3, 5)$

$= 5$

Problem 2

5. Sum of Manhattan distances of all goals

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



$$h(s_1) = d(s_1, G_1) + d(s_1, G_2)$$
$$= 7 + 3 = 10$$
$$h^*(s_1) = d(s_1, G_2) + d(G_2, G_1)$$
$$= 3 + 6 = 9$$

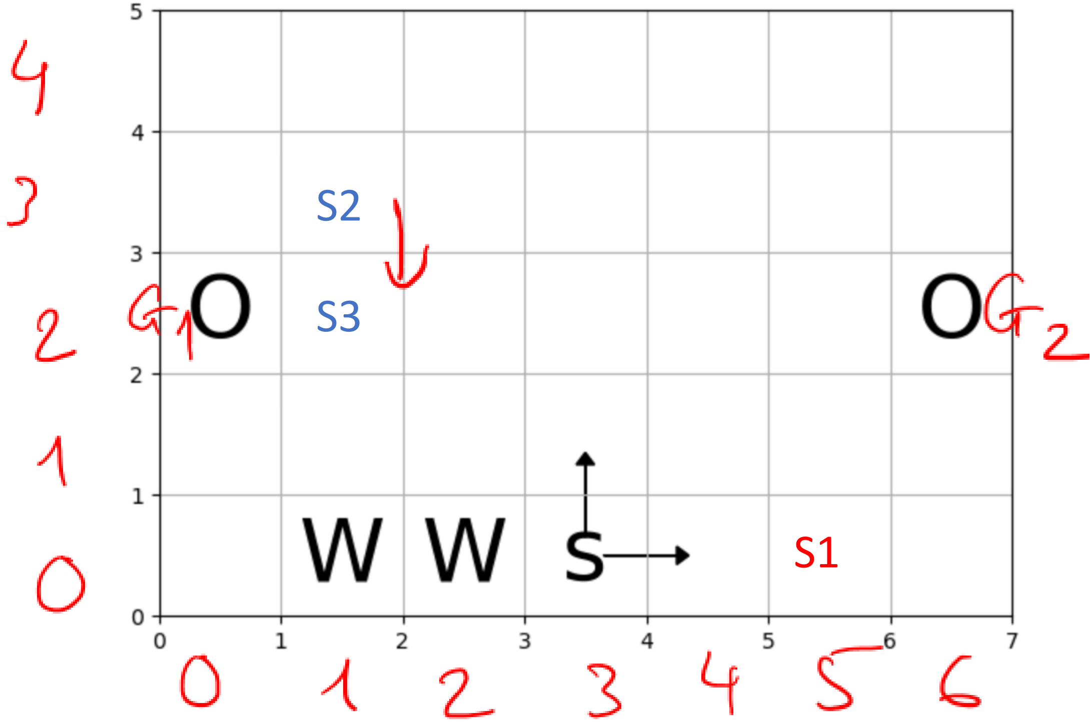
$\Rightarrow h(s_1) > h^*(s_1)$

$\Rightarrow$ Not admissible

Problem 2

5. Sum of Manhattan distances of all goals

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



$$h(s_2) = d(s_2, G_1) + d(s_2, G_2) = 2 + 6 = 8$$

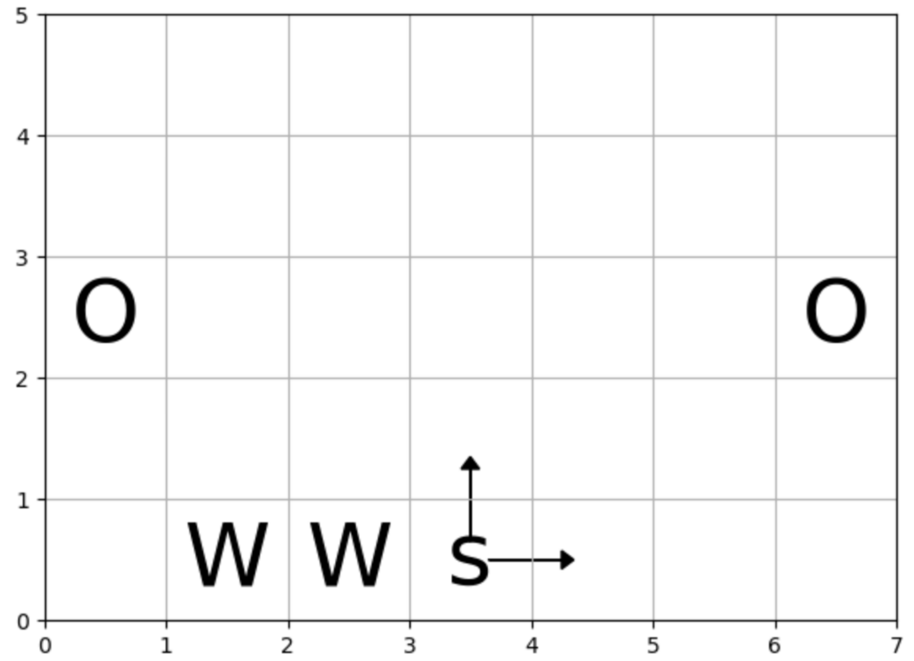
$$h(s_3) = d(s_3, G_1) + d(s_3, G_2) = 1 + 5 = 6$$

$$\underbrace{h(s_2)}_{\text{parent}} - h(s_1) > c(s_2, s_3) = 1 \Rightarrow \text{Not consistent.}$$

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 Farthest Goal heuristic: Admissible, Consistent
5. Sum of manhattan distances of all goals: Not admissible, Not consistent



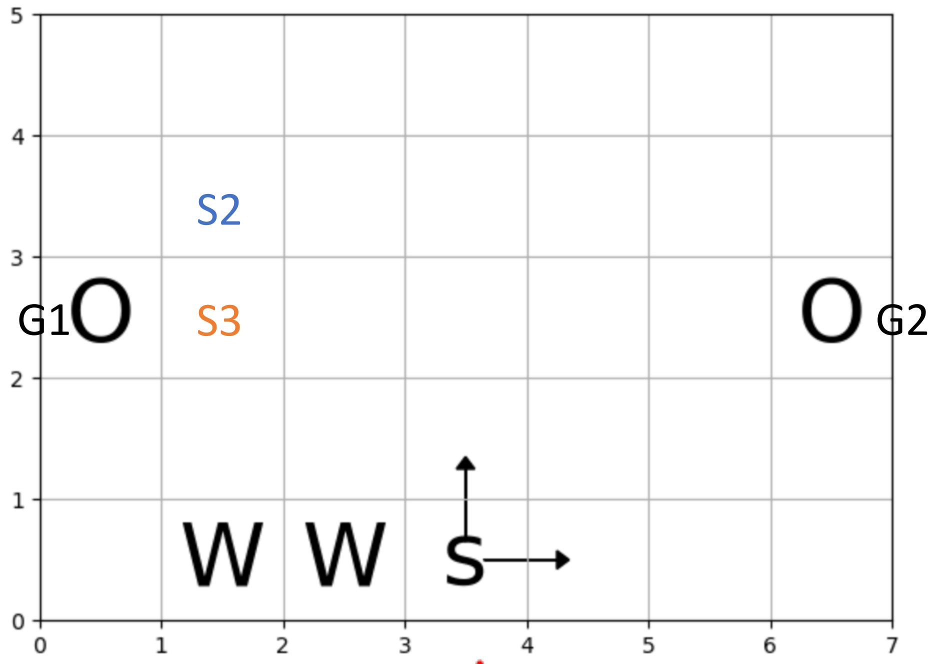
h(goal counting) > h(zero)
h(closest) > h(zero)
h(farthest) > h(zero)

h(farthest) > h(closest)
h(farthest) > h(goal counting)

Problem 2

$h(s_2) = ?$

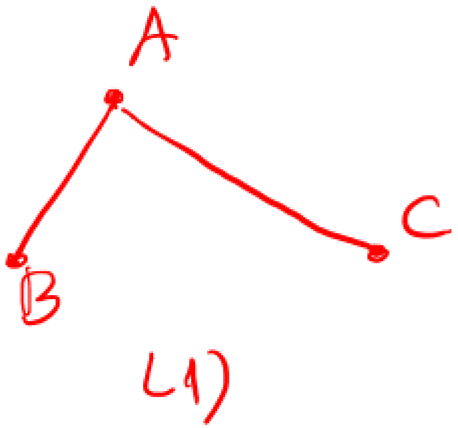
$h(s_3) = ?$

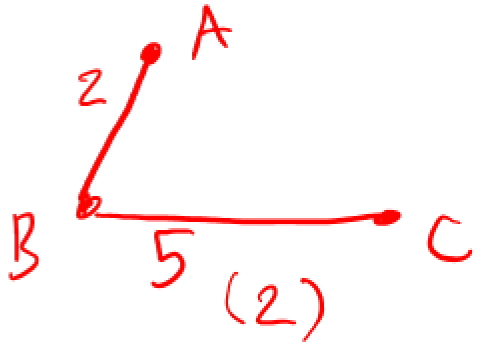


6. Minimum spanning tree

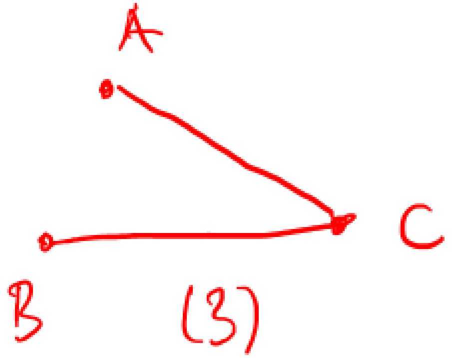
Admissible: Yes
Consistent: No
Time to calculate h: Medium

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





$h = 7$

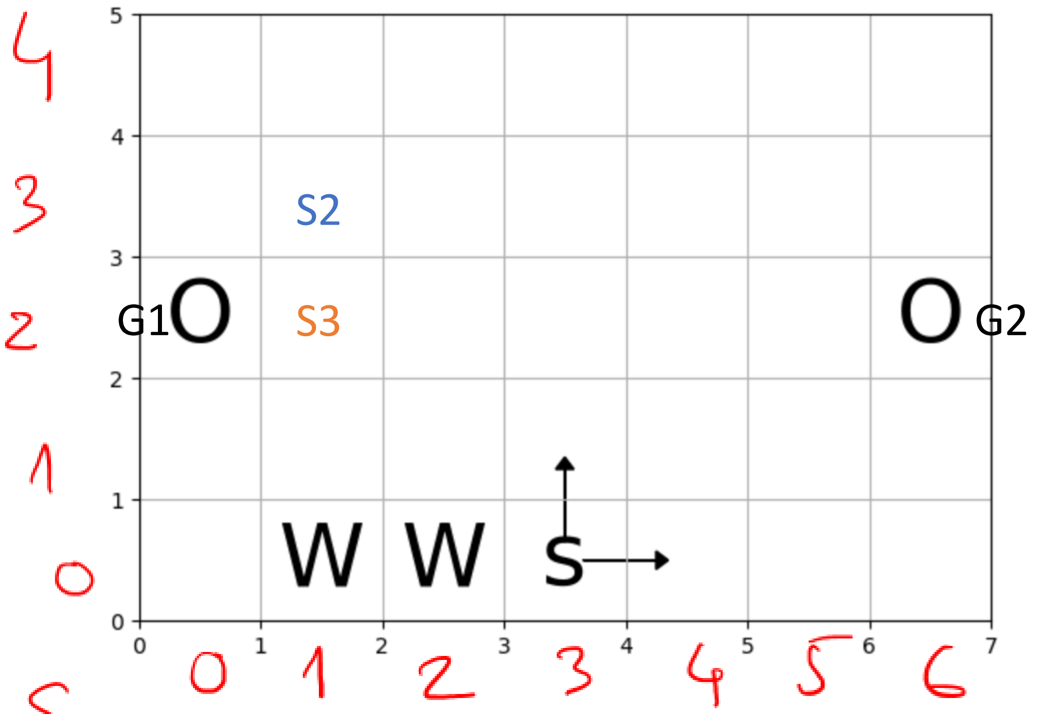


Problem 2

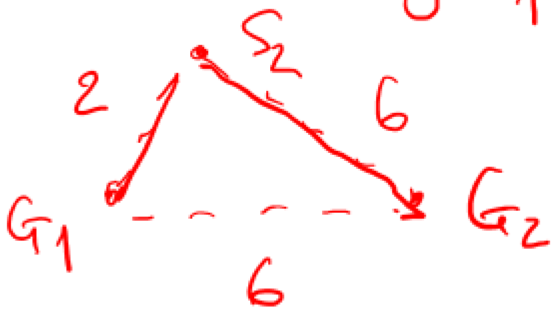
6. Minimum spanning tree

~~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



$h(s_2) = ?\quad 2+6=8$



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

$h(s_2) - h(s_3) = 2 > c(s_2, s_3) = 1$