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

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

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

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

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

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

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

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

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

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

F = facts/predicates/fluents

- A **problem** in STRIPS is a tuple $P = \langle F, O, I, G \rangle$:
  - F stands for set of all atoms (boolean vars)
  - O stands for set of all operators (actions)
  - $I \subseteq F$ stands for initial situation
  - $G \subseteq F$ stands for goal situation

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- Operators $o \in O$ **represented** by
  - the Add list $Add(o) \subseteq F$
  - the Delete list $Del(o) \subseteq F$
  - the Precondition list $Pre(o) \subseteq F$

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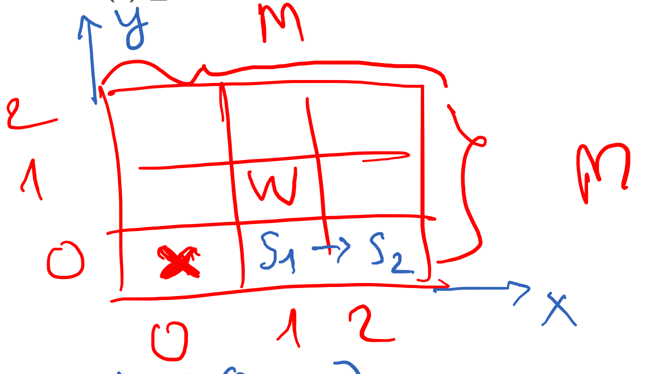


$$I = \{at(0,0), visited(0,0)\}$$

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

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

$\mathbf{O} = \{move(x, y, x', y')$:

- *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* }

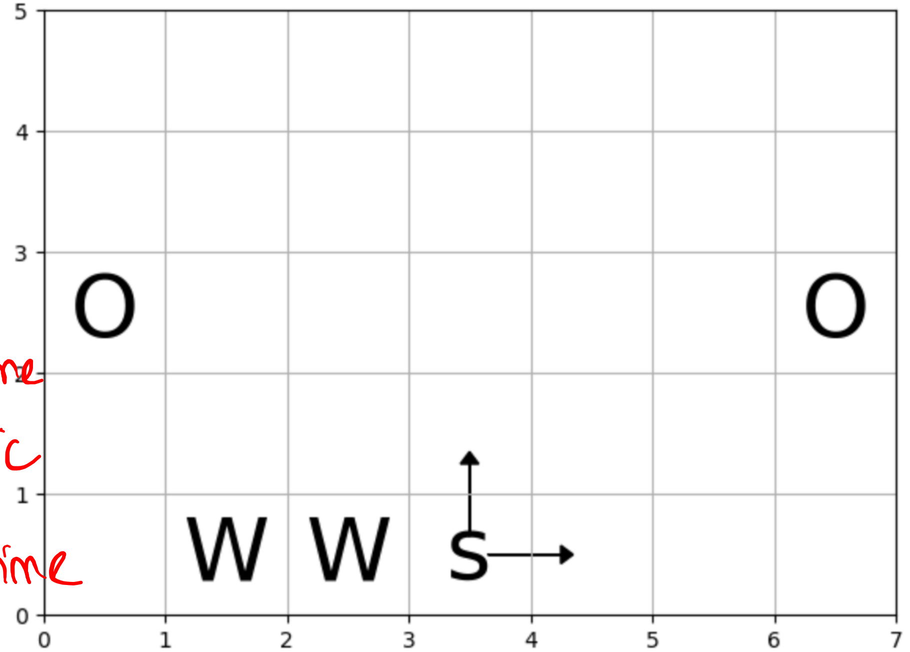
become True after the action

become False after the action

prec: at(1,0)
add: at(2,0), visited(2,0)
del: at(1,0)

Problem 2

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



Bad heuristic: ↑ expand more node + ↓ calculation time of the heuristic

Good heuristic: ↓ expand less node + ↑ calculation time of the heuristic.

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

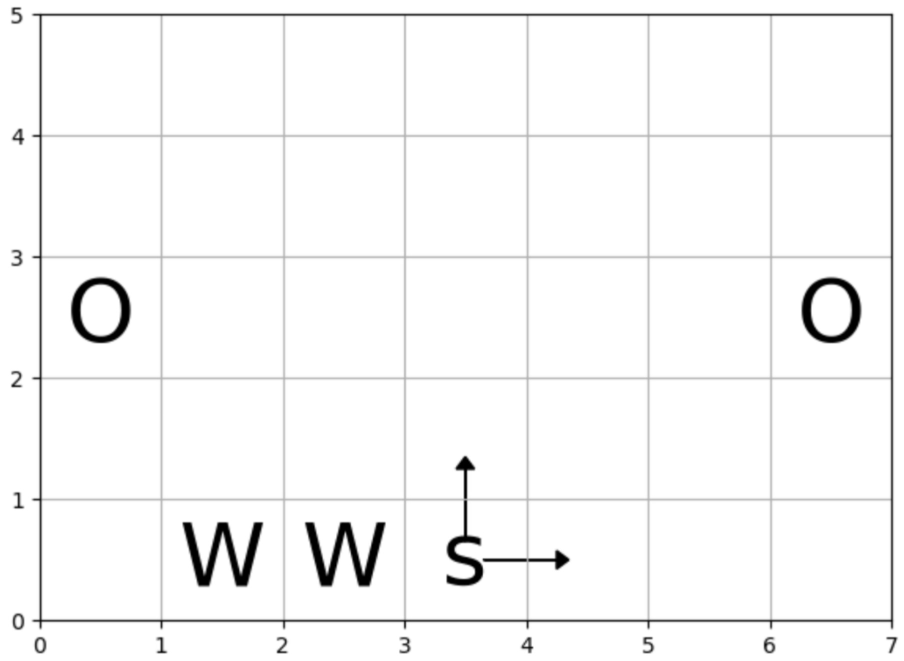
(1) (2)

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

Problem 2

1. Zero heuristic h = 0

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



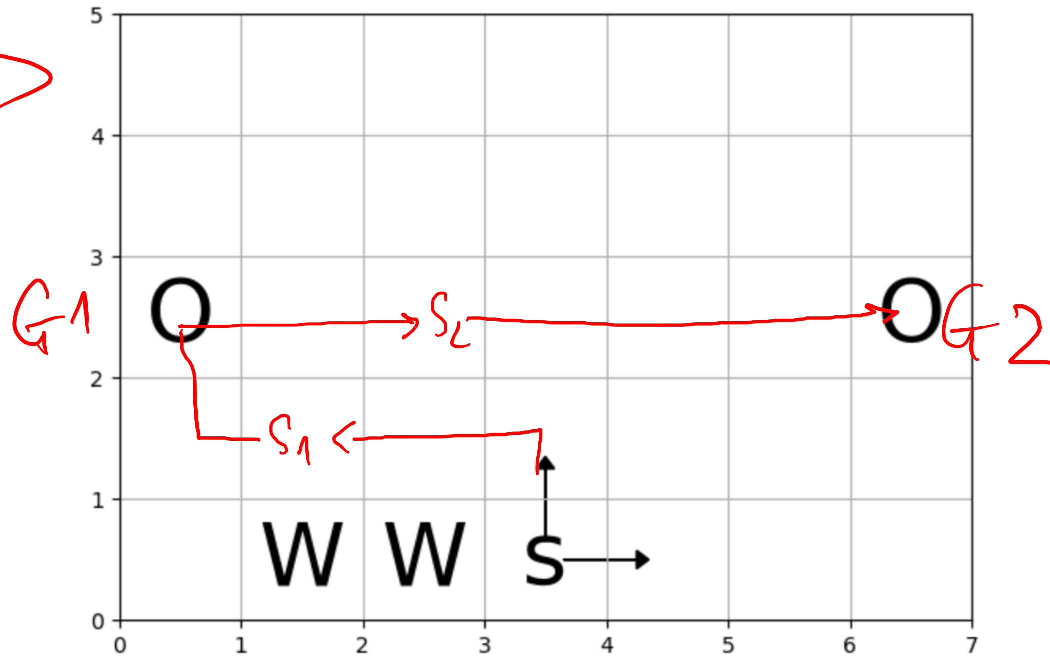
Problem 2

2. Goal-counting heuristic

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

$h(s_1) = 2$

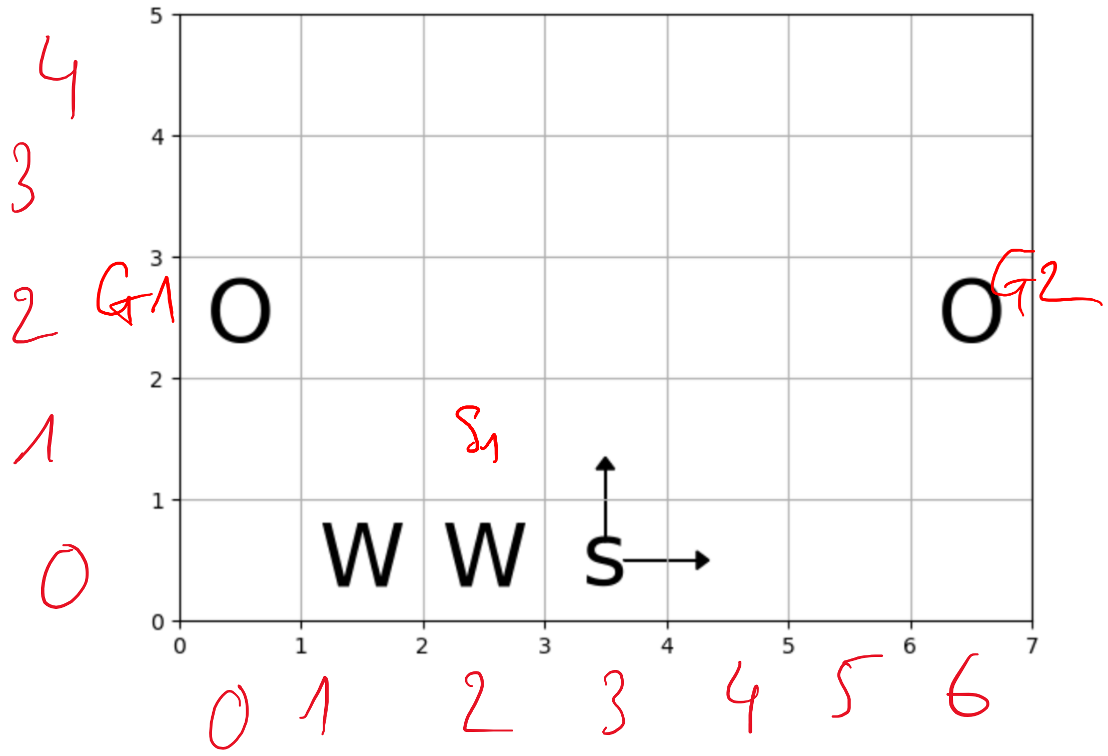
$h(s_2) = 1$



Problem 2

3. Manhattan Distance to Closest Goal heuristic

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

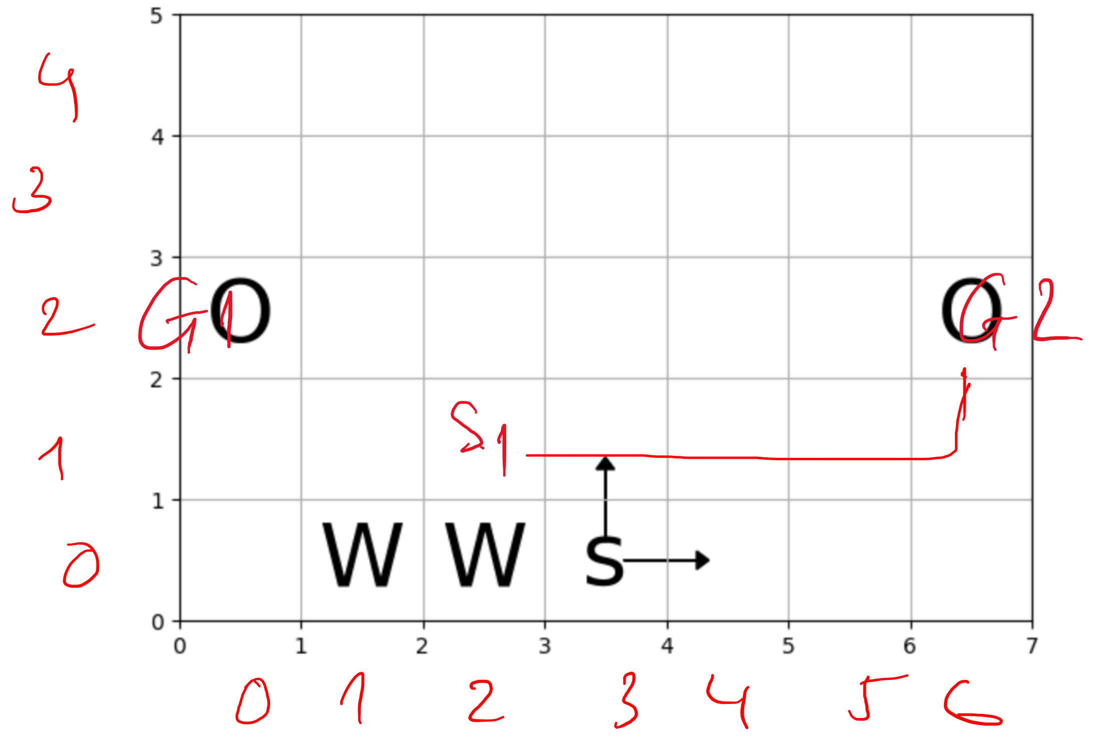


$h(s_1) = d(G1, s1) = 3$

Problem 2

4. Manhattan Distance to Farthest Goal heuristic

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

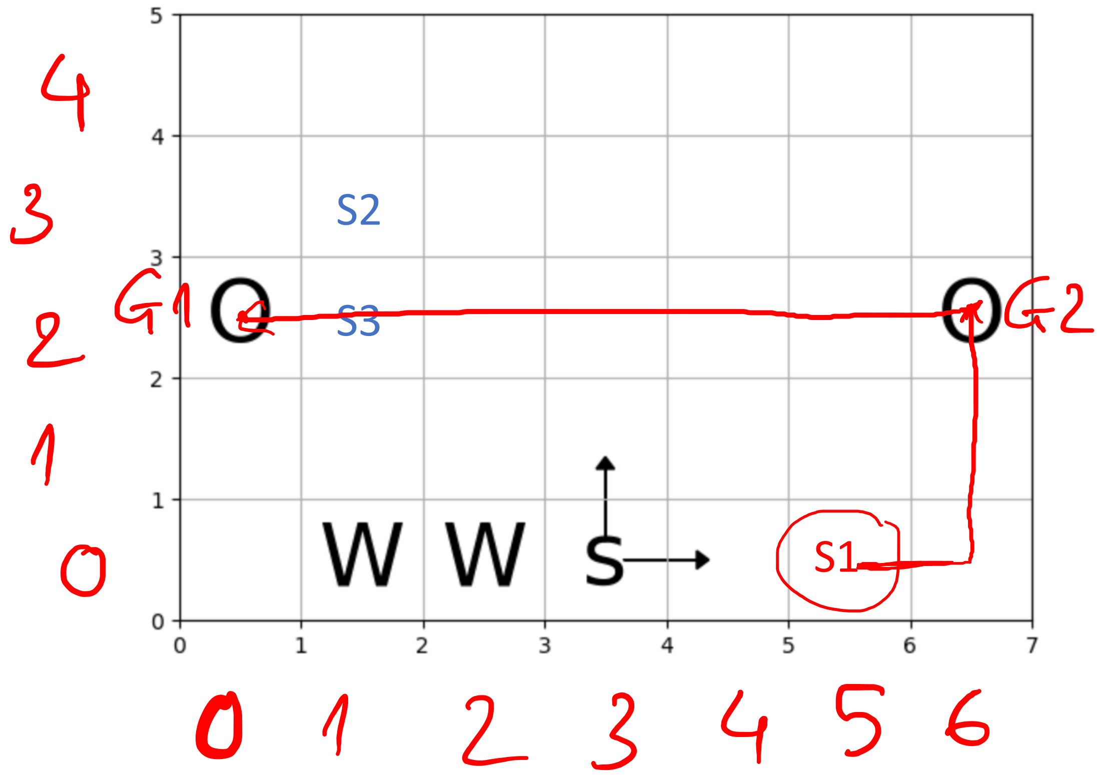


$h(s_1) = d(s_1, G2) = 5$

Problem 2

5. Sum of Manhattan distances of all goals

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



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

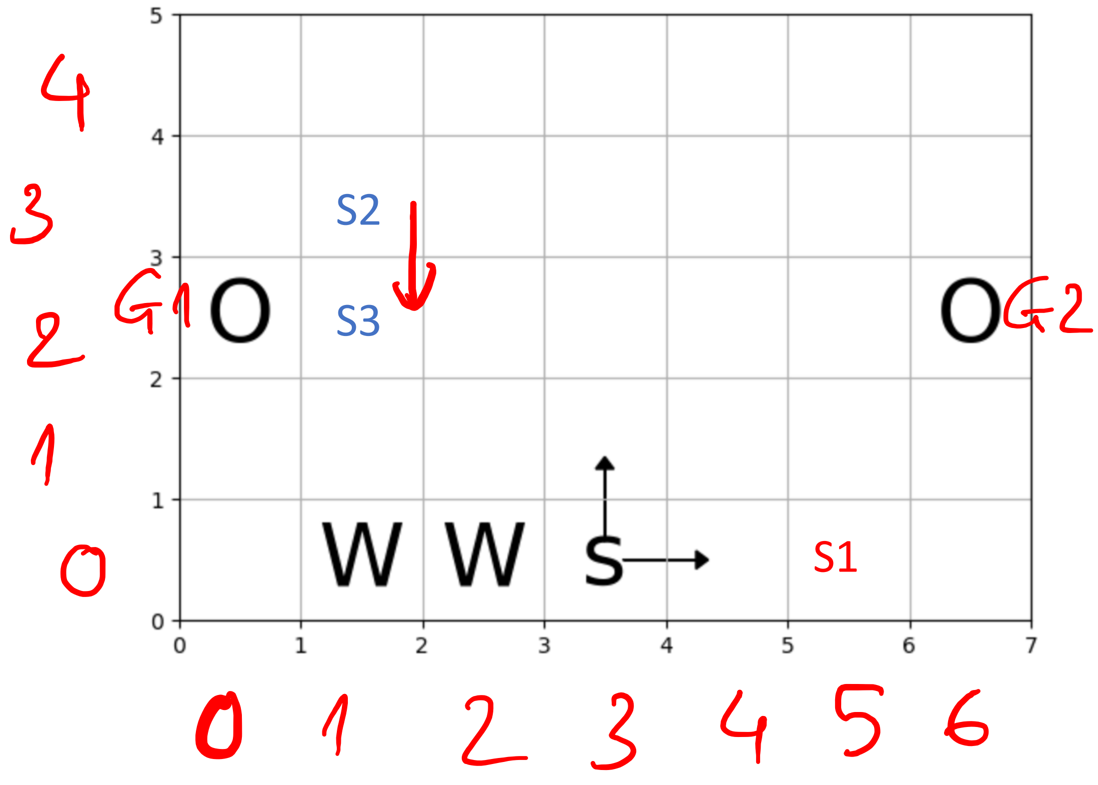
$h^*(s_1) = d(s_1, G2) + d(G2, G1)$
$= 3 + 6 = 9$

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

Problem 2

5. Sum of Manhattan distances of all goals

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



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

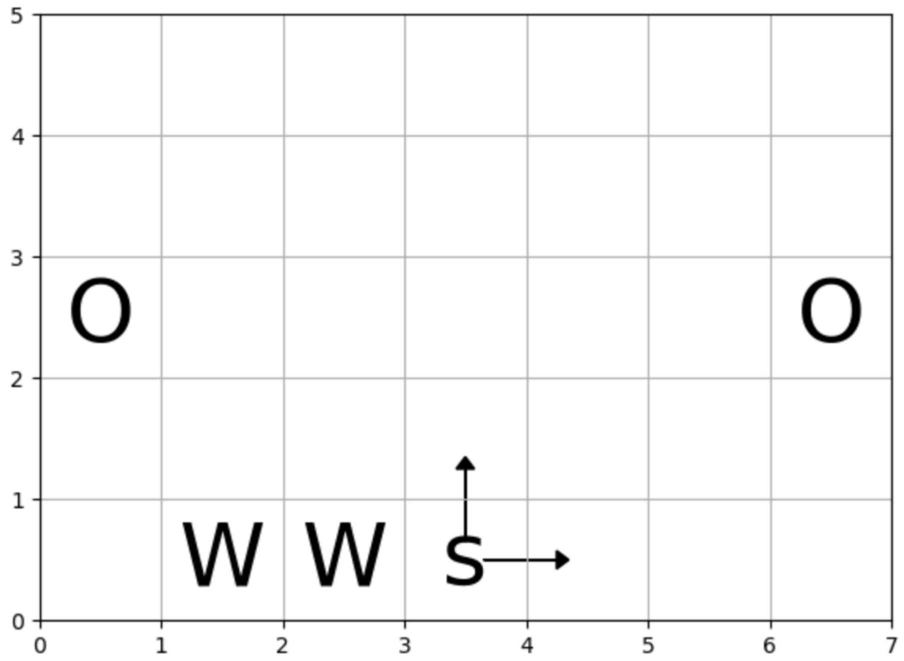
$$h(s_3) = d(s_3, G1) + d(s_3, G2) = 1 + 5 = 6$$

$$h(s_2) - h(s_3) = 8 - 6 = 2 > c(s_2, s_3) = 1. \Rightarrow \text{Not consistent}$$

Problem 2

Dominate relation

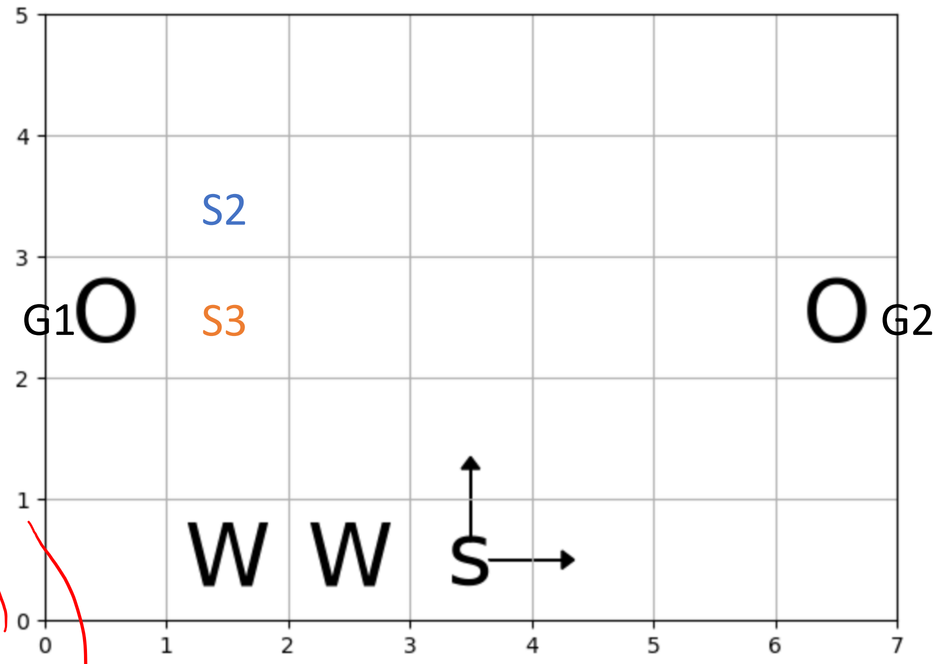
1. Zero heuristic: Admissible, Consistent
2. Goal-counting heuristic: Admissible, Consistent
3. Manhattan Distance to Closest Goal heuristic: Admissible, Consistent
4. Manhattan Distance to Farthest Goal heuristic: Admissible, Consistent
5. ~~Sum of manhattan distances of all goals: Not admissible, Not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



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

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

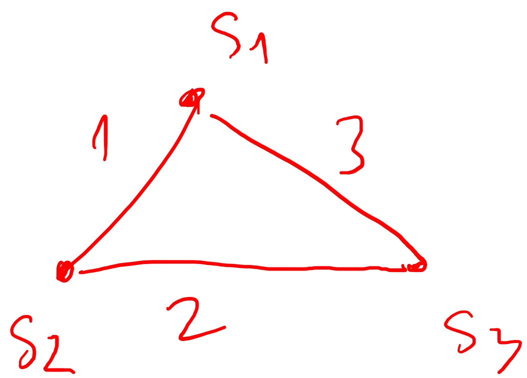
Problem 2

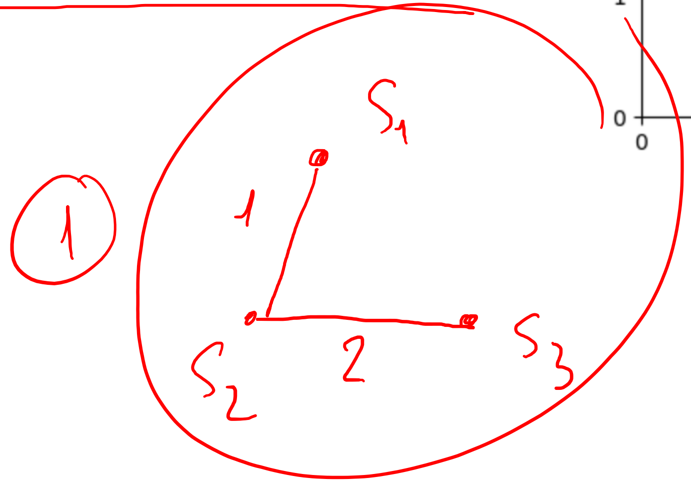


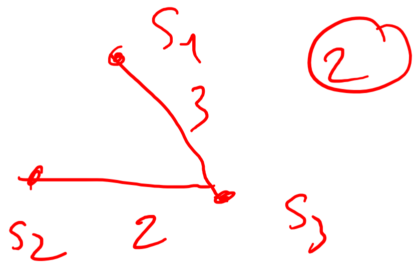
6. Minimum spanning tree

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

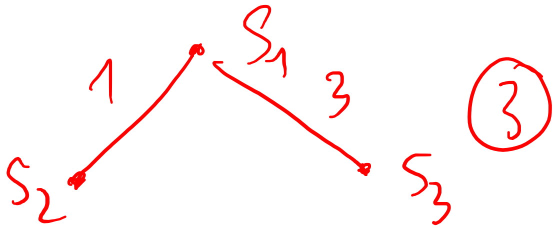
Minimum spanning tree: Only select a subset of edges to connect all vertices and the total cost is minimum







minimum total cost

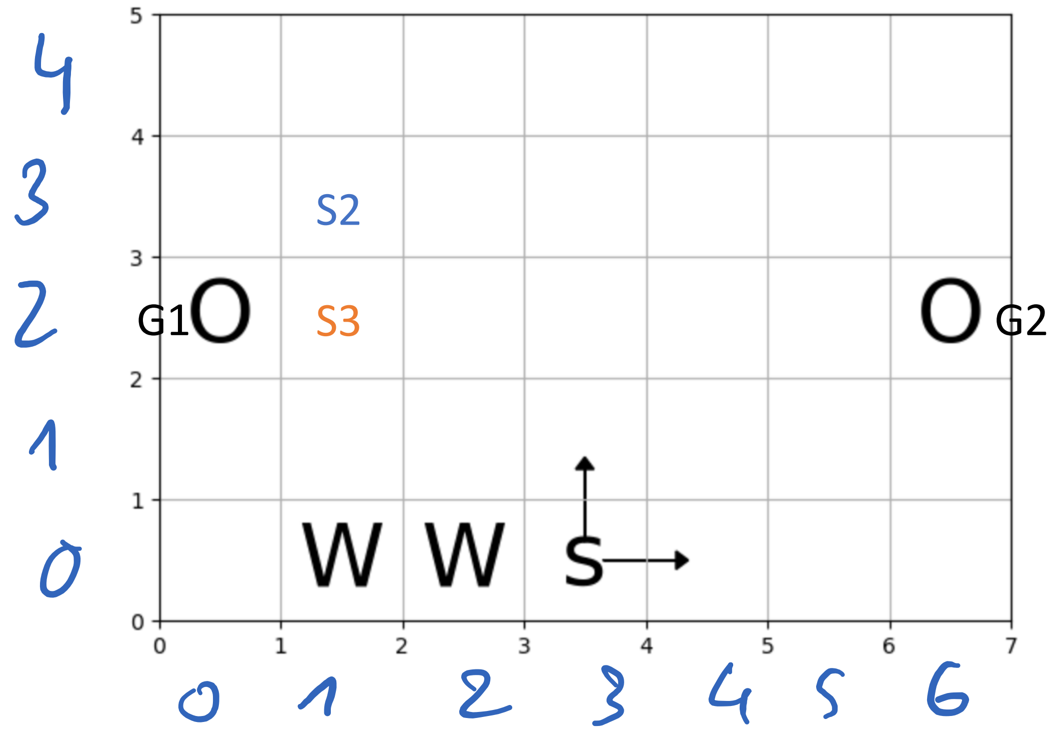


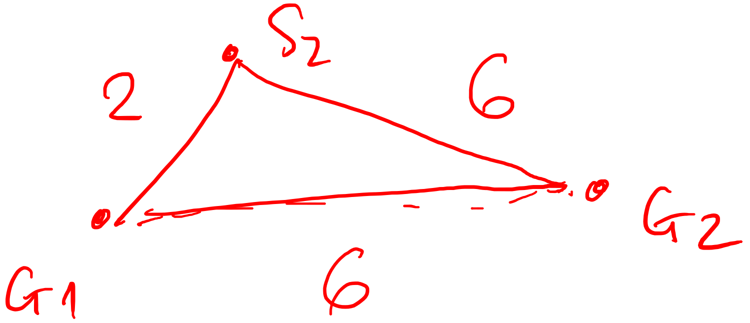
Problem 2

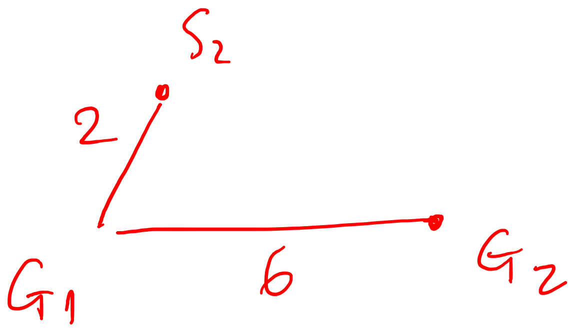
6. Minimum spanning tree

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







$\Rightarrow 2+6=8$

$h(S_2) = 8$

$h(S_3) = ?\ldots$