

# COMP90054 Workshop 3

Geye Guo

# 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).

# m x m Grid

		Agent		

$P = \{S, s0, SG, A, T, C\}$

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# Recap: Manhattan Problem

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- $S = \{\langle x, y, V' \rangle \mid x, y \in \{0, \dots, m-1\} \wedge V' \subseteq G\}$
- $s_0 = \langle (0, 0), G \setminus \{(0, 0)\} \rangle$
- $S_G = \{\langle (x, y), \{\} \rangle \mid x, y \in \{0, \dots, m-1\}\}$
- $A(\langle x, y, V' \rangle) = \{(dx, dy) \mid$ 
  - $dx, dy \in \{-1, 0, 1\}$
  - $\wedge |dx| + |dy| = 1$
  - $\wedge x + dx, y + dy \in \{0, \dots, m-1\}$
  - $(x + dx, y + dy) \notin W \}$
- $T(\langle x, y, V' \rangle, (dx, dy)) = \langle x + dx, y + dy, V' \setminus \{(x + dx, y + dy)\} \rangle$
- $c(a, s) = 1$

# Problem 1

Reformulate the state-space model from *Review and Recap* as a STRIPS problem  $P = \langle F, O, I, G \rangle$

# STRIPS Model

- 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**

# STRIPS Model

- 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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# Problem 1

$$F_1 = \{ \underline{x(i)}, \underline{y(i)} \mid i \in \{0, \dots, m-1\} \}$$

- $F = \{at(x, y), visited(x, y) \mid x, y \in \{0, \dots, m-1\}\}$
- $O = \{move(x, y, x', y'):$ 
  - Prec:
  - Add:
  - Del:
- $I = \{at(0, 0), visited(0, 0)\}$
- $G = \{visited(x, y) \mid (x, y) \in G'\}$

# Problem 1

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

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

- Prec:  $at(x, y)$

- Add:  $at(x', y'), visited(x', y')$

- Del:  $at(x, y)$

- | for each adjacent  $(x, y)$ ,  $(x', y')$ , and  $(x', y') \notin W$

$$x, y, x', y' \in \{0, \dots, m-1\}$$
$$|x-x'| + |y-y'| = 1$$

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

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

# Problem 1

**notWall(x,y)**

- $F = \{at(x, y), visited(x, y) \mid x, y \in \{0, \dots, m - 1\}\}$
- $O = \{move(x, y, x', y'):$ 
  - Prec:  $at(x, y)$  **notWall(x,y), notWall(x', y')**
  - Add:  $at(x', y'), visited(x', y')$
  - Del:  $at(x, y)$

| for each adjacent  $(x, y), (x', y')$
- $I = \{at(0, 0), visited(0, 0)\}$
- $G = \{visited(x, y) \mid (x, y) \in G'\}$

# Problem 2

G1						G2
	Wall	Wall	Startin g point			

## Problem 2

- Goal-counting
- Manhattan distance to the closest goal(position) heuristic
- Manhattan distance to the furthest goal(position) heuristic
- Your own heuristic...

# Recap: Dominant Relation

- If heuristic  $h_1$  dominates heuristic  $h_2$ :
- Then we will have  $h_1(s) \geq h_2(s)$ , for all  $s$  belongs to state space  $S$
- And both  $h_1$  and  $h_2$  need to be admissible

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# Common Heuristic for Manhattan Problems

- Null Heuristic:  $h = 0$  for all state
- Goal counting:  $h = |V'|$
- Manhattan to the closest:  $h = \min(\text{Manhattan}(\text{all food}))$
- Manhattan to the furthest:  $h = \max(\text{Manhattan}(\text{all food}))$
- Average of these two:  $h = \text{average}(\text{min}, \text{max})$
- Sum Manhattan:  $h = \text{sum}(\text{Manhattan}(\text{all food}))$
- Minimum Spanning Tree:  $h = \text{len}(\text{minimum spanning tree}(\text{all food}))$



# Properties of Heuristic functions

**Definition (Safe/Goal-Aware/Admissible/Consistent).** Let  $\Pi$  be a planning task with state space  $\Theta_{\Pi} = (S, L, c, T, I, S^G)$ , and let  $h$  be a heuristic for  $\Pi$ . The heuristic is called:

- **safe** if  $h^*(s) = \infty$  for all  $s \in S$  with  $h(s) = \infty$ ;
- **goal-aware** if  $h(s) = 0$  for all goal states  $s \in S^G$ ;
- **admissible** if  $h(s) \leq h^*(s)$  for all  $s \in S$ ;
- **consistent** if  $h(s) \leq h(s') + c(a)$  for all transitions  $s \xrightarrow{a} s'$ .

# Is Manhattan furthest heuristic consistent?

- Being consistent: reduced value  $h(s) - h(s') \leq 1$
- Every time perform an action using this heuristic,
- There are 3 possible outcome:
  1. one step closer:  $h(s) - h(s') = 1$ , also consistent
  2. one step further:  $h(s) - h(s') = -1$ , also consistent
  3. furthest food change

# Furthest Manhattan heuristic



# Furthest Manhattan heuristic

- For state  $s$ , agent position:  $P1$ , furthest coordinate:  $G1$
- For state  $s'$ , agent position:  $P2$ , furthest coordinate:  $G2$
- $h(s) = \text{Distance}(P1, G1)$ ,  $h(s') = \text{Distance}(P2, G2)$

Is it possible that  $h(s) > h(s')$ ?

# Furthest Manhattan heuristic

For state  $s$ , agent position:  $P1$ , furthest coordinate:  $G1$

For state  $s'$ , agent position:  $P2$ , furthest coordinate:  $G2$

-  $h(s) = \text{Distance}(P1, G1)$ ,  $h(s') = \text{Distance}(P2, G2)$

Is it possible that  $h(s) > h(s')$ ?

- Which means  $h(s) \geq h(s') + 1$
- i.e,  $h(s') \leq h(s) - 1$

And we also have

- $h(s) - 1 \leq \text{Distance}(P2, G1) \leq h(s) + 1$

In conclusion,

- $h(s') = \text{Distance}(P2, G2) \leq \text{Distance}(P2, G1)$
- Furthest food should not change

# Furthest Manhattan heuristic

- If the furthest coordinate changes, is it possible that  $h(s) > h(s')$ ?
- Impossible!
- And  $h(s) - h(s') \leq 0$
- Reduced value is always  $\leq 1$
- This is **consistent**

# Sum Manhattan heuristic

			Agent	G1	G2	
	Wall	Wall				

# Minimum Spanning Tree Heuristic

- Admissible
- Not consistent

