# CS2109s - Tutorial 3

Eric Han (TG12-TG15) Feb 15, 2024

#### Important admin

1. TG15, PS4 - PS8 will be marked by **Guo Mingqi** due to my high teaching workload [By Teaching Committee/Rizki].

#### Problem Set 2

- 1. Q1.2 A\*Star algorithm
  - 1.1 Check if node is visited
  - $1.2\,$  PQ not updated correctly when encountering a path to a child node with a lower cost.
- 2. Q2.2 TSP Goal state cannot be known explicitly state explicitly that goal state cannot be known, if not i do not know if you are trying to define it or not.
- 3. Q2.6 Abuse of random.sample to create the initial state, it will give the desired effect but this is abuse!
- 4. Q1.3 Most explanations are sloppy but since its 1 marks as long as you explain in line of the max rows/cols, I will award you; Learn to explain properly.

#### Task 1.3 - Why heuristic is consistent and admissible [Wenzhong 2324S1/TG4].

Let the shape of the 2D Rubik cube be (R, C). Let x be the number of misplaced piece in state n, and  $M = \max(R, C)$ .

My heuristic is:  $h(n) = \frac{x}{M}$ 

## Admissibility (but not necessary)

Heuristic is admissible since in the original puzzle, each move will correct at most M number of pieces, and the heuristic is saying each move is the best move possible (i.e. correct M number of pieces), hence this heuristic can never be larger than the actual number of moves. =>  $h(n) \le h^*(n)$ 

#### Consistency

Let n be a state in the puzzle, and n' be the direct successor of n (i.e. the children of n) Denote G to be the goal state.

- 1. From my heuristic  $h(n) = \frac{x}{M}$
- 2. Since every move can at most put M pieces into the right place, n' can have at least x M misplaced pieces

3. Thus, 
$$h(n') \ge \frac{x-M}{M} = \frac{x}{M} - 1$$

- 4. Also, for this puzzle c(n, a, n') = 1 given that a is a valid move that move n to n', as each move of the Rubik cube have uniform cost.
  - $c(n, a, n') + h(n') \ge 1 + \frac{x}{M} 1 = \frac{x}{M} = h(n)$
  - $h(n) \le c(n, a, n') + h(n')$
- 5. Therefore by definition, h(n) is consistent.
- 6. Since consistent imples admissible and h(g) = 0, so h(n) is admissible.

# Question 1

Tic-Tac-Toe - Use the minimax to determine the first move of the player.

Eval(n) = P(n) - O(n), where P(n), O(n) are the no. of winning lines

#### Recap

- 1. What is the MINIMAX algorithm? Why is it used?
- 2. What are the ingredients needed to setup a minimax problem?
- 3. What is the impact of choosing min/max in our computation?
- 4. [@] When was MINIMAX famously used in Al?

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- Actors: Min/Max, Leaf Cost
- IBM Deep Blue versus Garry Kasparov in Chess.

#### Question 1a



Figure 1: First move 2-ply deep search space

### Answer 1a



Figure 2: First move 2-ply deep search space

## **Question 1b**



Figure 3: Second move 2-ply deep search space solution

### Answer 1b



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# Question 2 [G]

Run through the  $\alpha$ - $\beta$ :

- a. Right to Left
- b. Left to Right

Then determine if the effectiveness of pruning depends on iteration order.



Figure 5: Alpha-Beta Tree

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- 2. What kind of efficiency do you gain?
- 3. What is deep cutoff?

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Save on static evaluation and move generation.

#### Answer



Nonogram, aka Paint by Numbers, is a puzzle where cells are colored or left blank according to the numbers at the side of the grid.

	3	1	1	4	4
1 1 1					
12					
22					
2					
1					

			З	1	1	4	4
1	1	1					
	1	2					
	2	2					
		2					
		1					



Figure 9: Solved

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- 1. What are the ingredients needed for informed search?
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Un/Informed Search (Path): State space, Initial, Final, Action, Transition

- Uninformed: BFS, UCS, DFS
- Informed: GBFS, A\*

Local Search (Goal): Inital state, Transition, Heuristic/Stopping criteria

• Hill Climbing, Sim. Annealing, Beam, Genetic...

Adversarial Search: Actors, Actions, Leaf Costs

• Minimax, Alpha-Beta

# Question 3a [G]

Having learnt both informed search and local search, you think that local search is more suitable for this problem. Give 2 possible reasons why informed search might be a bad idea.

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## Answer 3a

- We are only interested in the final solution.
- Search space is large  $O(2^{n \times n})$  for a  $n \times n$  grid.
- May not be solvable? In that case we can get a config that minimize violations.

Question 3b / 3c / 3d / 3e [G]

Find a formulation for Local Search.

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Find a formulation for **Local Search**.

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Answer 3b / 3c / 3d / 3e
```

 $n \times n$  boolean matrix, where each element is either true (if the corresponding cell is colored) or false (if the corresponding cell is not colored).

- Inital state is an n × n boolean matrix with every row having random permutations
  of boolean vector satisfying row constraints, while the rest of the entries are set to
  false.
- **Transition**: we can pick a random row and generate the list of neighbours with the corresponding row permuted satisfying row constraints.
- Heuristic/Stopping criteria: number of instances where the constraints on the column configurations are violated.

# Question 3f [G]

Local search is susceptible to local minimas. Describe how you can modify your solution to combat this.

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# Answer 3f

- Introduce random restarts by repeating local search from a random initial state
- Simulated annealing search to accept a possibly bad state with a probability that decays over time
- beam search to perform k hill-climbing searches in parallel.

# Question 4 [@]

In order for node B to NOT be pruned, what values can node A take on?



Figure 10: Find A so the B is not pruned.

< S -inf inf

< a2 -inf inf > a2 -inf 9 < a2 -inf 9 > a2 -inf 7 < a2 -inf 7 < b2 -inf 7 > b2 5 7 < b2 5 7 > b2 5 7 > a2 -inf 5 > S 5 inf

< S 5 inf< a1 5 inf > a1 5 9 < a1 5 9 < b1 5 9 > b1 5 9 < b1 5 9 > b1 5 9 < b1 5 9 > b1 Pruned val >= beta:  $9 \ge 9$ > a1 5 9 < a1 5 9 > a1 5 6 > S 6 inf

Pruned when  $A \ge 9$ , Not pruned when  $A \le 8$ 

To help you further your understanding, not compulsory; Work for Snack/EXP!

### Tasks

- 1. Trace Manually/Use code Figure 11 to see the full capability.
  - $1.1 \ \ Some \ code \ implemented \ in \ https://github.com/eric-vader/CS2109s-2324s2-bonus$
- 2. How can we benefit from  $\alpha$ - $\beta$ 's efficiency?



Figure 11: Alpha-Beta Example (Credit MIT)

### Study More

- 1. MIT Lecture https://youtu.be/STjW3eH0Cik?si=YcnrXUJko5jjLzB0
- 2. IBM Deep Blue -

https://www.sciencedirect.com/science/article/pii/S0004370201001291

- 3. Game Theory Concepts Within AlphaGo https://towardsdatascience.com/gametheory-concepts-within-alphago-2443bbca36e0
- 4. What Game Theory Reveals About Life, The Universe, and Everything https://youtu.be/mScpHTIi-kM?si=CLagrjz3WVi-EkXG

# **Buddy Attendance Taking**

- 1. [@] and Bonus declaration is to be done here; You should show bonus to Eric.
- 2. Attempted tutorial should come with proof (sketches, workings etc...)
- 3. Random checks will be conducted python ../checks.py T13



 $\label{eq:Figure 12: Buddy Attendance: https://forms.gle/jsGfFyfo9PTgWxib6$