[redacted]

1. Provide an argument in support of and one against each of the following statements.

    (a) According to the Church–Turing Hypothesis, any form of intelligence is computable.

    (b) The Turing Test remains the best measure of machine intelligence.

    (c) LLMs like GPT-5 demonstrate epistemic but not instrumental rationality.

    [By Huijuan Wang]

a) In support: Acceptance of the Symbol System Hypothesis (Newell, Simon) argues that intelligence consists of reasoning as symbol manipulation. Church-Turing states that any type of computation can be carried out on a turing machine.
=> Based on the implication that reasoning can be computational (Symbol-System + Church Turing) aka reasoning as symbols can be digitalized; intelligence as symbol manipulation is computable.

Against: Even with reasoning as symbol manipulation being computational, other aspects of intelligence, creativity, consciousness, etc may not be computational as they are not represented as symbol manipulation. => Intelligence in <u>any</u> form is not always computable

b) In support: The Turing test remains the best measure of intelligence because it observes the 6 subfields that cover <u>almost all of AI efforts</u>: (natural language processing for successful communication, knowledge representation and storage, automated reasoning to use stored information and draw new conclusions, machine learning to adapt / detect and extrapolate new patterns, computervision for perception, and robotics for manipulation) This allows the Turing test to focus on the behavior that should show intelligence at a broad scope which allows evaluation of a wide range of intellectual ability.

Against: The Turing test is not optimal due to reductionism; it reduces intelligence to some form of functionality. The Turing test does not include the full scope of intelligence but assesses an imitation of intelligent behavior overlooking internal processes, consciousness, understanding, etc.

c) In Support: LLM's demonstrate epistemic rationality by continuously updating when they receive new information in attempts to have correct/accurate beliefs that are well supported by evidence. LLM's do not demonstrate instrumental rationality based on the lack of goals and intrinsic beliefs. LLM's choose actions from what they are told in that specific moment but lack personal reasons for their actions such as virtues of faith or beliefs (long standing or gained through lifetime experience). Lastly LLM's cannot perform ingrained habituation where they behave from emotional response deeply ingrained that often is carried out without much thought due to familiarity and "muscle memory". Each new conversation is a new "state" where habits from the past are not carried over.

Against: LLM's do not use instrumental rationality for the previously listed reasons. However LLM's also do not use epistemic rationality because they do not have means to examine why they believe what they believe. They simply believe what they are told to, and cannot decipher whether the evidence they are given is accurate of reality.

[redacted]

3. A traveler starts at **checkpoint 1** on a straight hiking trail with checkpoints numbered from 1 to $n$. The traveler wants to reach checkpoint $n$ in the **least possible time**. Two actions are available:

1 2 3 4 5 6 - n

- **Walk:** move from checkpoint $s$ to $s + 1$, which takes exactly 1 minute.
- **Zipline:** move from checkpoint $s$ to $s + 2s$ (i.e., travel twice as far ahead), which takes exactly 2 minutes.

↳ 3s

**Questions**

(a) Describe how this problem can be represented as a **graph**. Clearly specify the **nodes**, **edges**, and **edge weights**.

(b) For $n = 12$, determine:

**Note:** The following algorithms (**BFS, DFS, IDS**) are treated as **uninformed search methods**. Even though the actions have different time costs (1 min vs. 2 min), **ignore edge weights** and assume all actions have equal cost when determining the expansion sequence and final path.

i. the **expansion sequence** (the order in which checkpoints are explored), and

ii. the **path** from checkpoint 1 to checkpoint $n$

using each of the following algorithms:

i. Breadth-First Search (BFS)

ii. Depth-First Search (DFS)

iii. Iterative Deepening Search (IDS)

Please list the expansion sequence and final path clearly, following the format below:

Expansion sequence: 1, 2, 3, 6, 7, 8, 9, 10, 11, 12

Path: $1 \rightarrow 3 \rightarrow 6 \rightarrow 12$

[By Feiyu Zhu]

a) nodes = checkpoints 1 to n, edges = paths between nodes (checkpoints) on trail

edge weight = time cost from start node to end node: either 1 or 2 mins depending on walk or zipline edge

The edges will go from one node to the next adjacent node for walking ex: 1→2 2→3 3→4 ... n-1→n

Edges will also go from node s to (2s + s) where s is the start node for ziplining (2s + s) ≤ n can't go farther than end node

↳ (3s)

ex: 1→3, 2→6, 3→9, 4→12 etc

b) $n=12$, assume all edge weights $=1$,

BFS : by layer

expansion sequence: 1, 2, 3, 6, 4, 9, 7, 5, 12

path: $1 \to 3 \to 4 \to 12$

DFS : all the way till deadend or goal

expansion sequence : 1, 3, 9, 10, 11, 12

path: $1 \to 3 \to 9 \to 10 \to 11 \to 12$

by depth

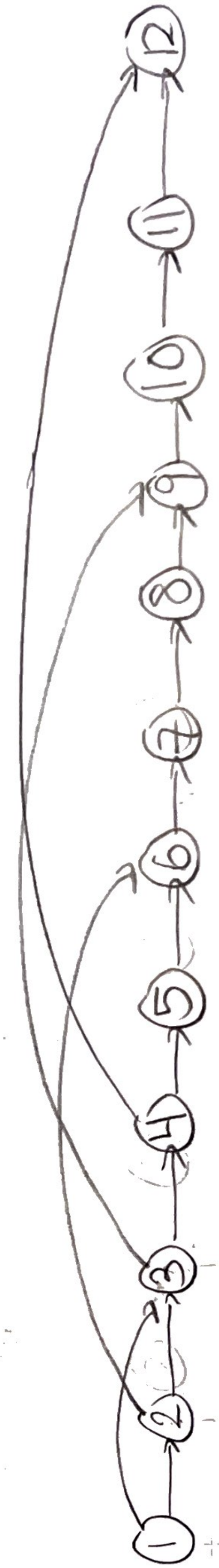
IDS

expansion sequence:

depth

$\overbrace{1}^{0}, \overbrace{1, 2, 3}^{1}, \overbrace{1, 2, 3, 3, 6, 4, 9}^{2}, \overbrace{1, 2, 3, 3, 6, 4, 9, 4, 9, 7, 5, 12}^{3}$

path: $1 \to 3 \to 4 \to 12$



[redacted]

4. Consider the following grid where each cell represents a node in the graph. The cost to move from one node to an adjacent node (up, down, left, or right) is always 1, except for obstacles, which cannot be traversed. The heuristic function $h(n)$ is the Manhattan distance from node $n$ to the goal node. The goal is to find the shortest path from the start node $S$ to the goal node $G$.

FIFO order (right, down, up, left)

$h(n)$ = manhattan distance
$g(n)$ = cost so far (+=1)
$f(n) = h(n) + g(n)$

Cost from one node to adjacent node = 1
except: obstacles cannot be traversed (X)
$G = (5,3)$

| y \ x | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|
| 1 | S | . | . | X | . |
| 2 | . | X | . | . | . |
| 3 | . | . | . | X | G |

Where:

- $S$ is the start node.
- $G$ is the goal node.
- $X$ represents an obstacle that cannot be traversed.
- . represents open nodes.

◯ means dequeued

**Questions** $h(n) = |x_1 - x_2| + |y_1 - y_2| \Rightarrow h(n) = |x_1 - 5| + |y_1 - 3|$

Tie breakers
1) FIFO (right, down, up, left)
2) lower $h(n)$

(a) What is the final path found by A*, and how is it found?

(b) Explain why the Manhattan distance heuristic is admissible in this case.

[By Yuecheng Li] $G = (5,3) = x_2, y_2$

still consider until ◯ dequeue

a) From S we calculate neighbors $f(n) = g(n) + h(n)$
$g(n) = 0$ since there is no cost yet

enqueue node options

(2,1)=6
(1,2)=6

right: for node $(2,1) = x_1, y_1$ $f(n) = 5+1 = 6$
$h(n) = |2-5| + |1-3| = 3+2 = 5$
we choose right since both $f(n) = 6$ and FIFO tie breaker says right comes before down

down: for node $(1,2) = x_1, x_2$ $f(n) = 5+1 = 6$
$h(n) = |1-5| + |2-3| = 4+1 = 5$
$f(n) = 6$ $h(n) = 5$

(1,2)=6
(3,1)=6

right: node (3,1)
$h(n) = |3-5| + |1-3| = 2+2 = 4$
$g(n) += 1 = 2$ $f(n) = 6$

node (3,1) and node (1,2) still both in list and tie @ $f(n) = 6$, by FIFO tie breaker we choose (3,1) because right is before down

(1,2)=6
(3,2)=6

down: node (3,2) $h(n) = 3$
$h(n) = |3-5| + |2-3| = 2+1 = 3$ $f(n) = 6$
$g(n) = 3$

nodes (1,2) and (3,2) both have $f(n) = 6$ and FIFO = down, therefore we choose node with lower $h(n) \Rightarrow 3 < 5$ So we choose node (3,2)

(1,2)=6
(4,2)=6
(3,3)=6

right: node (4,2)
$h(n) = |4-5| + |2-3| = 1+1 = 2$
$h(n) + g(n) = 2 + 4 = 6 = f(n)$
g-tie: says choose right as it is first in FIFO (4,2)

down: node (3,3)
$h(n) = |3-5| + |3-3| = 2$
$g(n) = 4$ $f(n) = 6$

down (1,2)
$f(n) = 6$
$h(n) = 5$

down (3,3) $f(n) = 6$

down (1,2) $f(n) = 6$

(1,2)=6
(3,3)=6
(5,2)=6

right: node (5,2)
$h(n) = |5-5| + |2-3| = 1$ $g(n) = 5$
$f(n) = 6$

we choose node (5,2) because of FIFO tie breaker

(5,3)=6
(5,1)=8
(3,3)=6
(1,2)=6

| | | | | |
|---|---|---|---|---|
| down node (5,3) <br> $h(n)=\lvert 5-5\rvert+\lvert 3-3\rvert=0$ <br> $f(n)=g(n)=6$  $h(n)=0$ <br> 6<8 down has lower f(n) | up node (5,1) <br> $h(n)=\lvert 5-5\rvert+\lvert 1-3\rvert$ <br> $=2$ <br> $f(n)=h(n)+g(n)$ <br> $=6+2$ <br> $=8$ | down node (3,3) <br> $h(n)=2$ <br> $f(n)=6$ | down node (1,2) <br> $h(n)=5$ <br> $f(n)=6$ |

node (5,3) has lowest h(n) so we choose (5,3) even with f(n) tie and FIFO tie
after deque of node (5,3) end goal test to see (5,3) = Goal end we terminate
we have reached (5,3) which is the goal node

optimal path by A* from S to G is $\underbrace{[\text{right, right, down, right, right, down}]}$

The final path by A* is

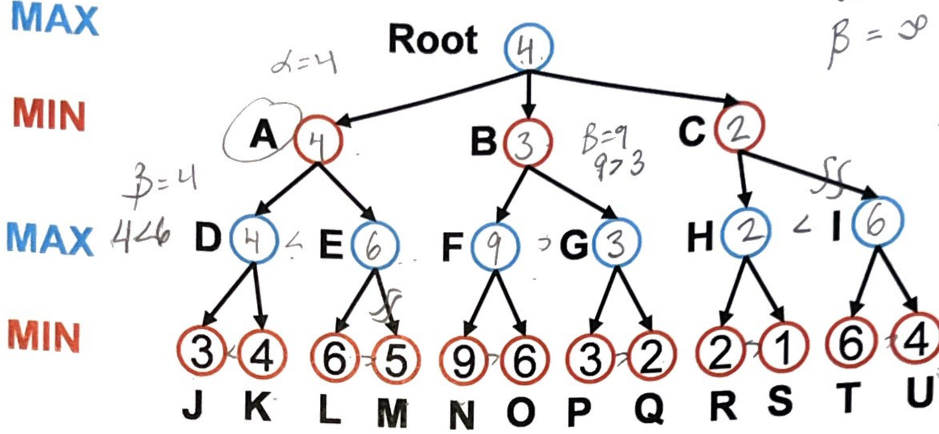
It is found by using the start node S = (1,1), end node G = (5,3)
heuristic function $h(n)=|x_1-5|+|y_1-3|$, $f(n)=h(n)+g(n)$, where f(n)
is used to choose which node to explore next, g(n) is the cost to get to node n
which increments by 1. I used FIFO tie breaker with order of (right, down, up, left)

b) Manhattan distance is admissible (optimistic) because it is the exact solution of a relaxed version of this problem. Manhattan distance is the shortest distance (given you have to move up, left, right or down and cannot move horizontal) without the obstacles which only can make the solution greater and and less optimal. In other words the optimal solution of a relaxed problem given by the Manhattan distance cannot be worse than the optimal solution once obstacles are introduced. The Manhattan distance will never overestimate the exact minimal cost.

[redacted]

2agent

5. A robotics company is developing a decision-making system for a two-agent competitive scenario. The decision tree below represents possible outcomes, where utility values are displayed beneath each terminal state. Blue circles represent Agent $A$ (who aims to maximize the utility), while red circles represent Agent $B$ (who aims to minimize the utility). When exploring possible decisions, the system processes options from left to right. *Use the format "(node, value)" to represent a node in your answer. For example, (K, 4), (M, 5).*




a) (Root, 4), (A, 4), (B, 3), (C, 2), (D, 4), (E, 6), (F, 9), (G, 3), (H, 2), (I, 6)

a) • Determine the utility values that would be propagated upward through the tree using the minimax algorithm. Indicate your answer by writing the backed-up values at each internal node in the tree above. *Write your answer from node Root, A to node I.*

b) • Identify which nodes would be skipped during the search process if using $\alpha$-$\beta$ pruning algorithm. Mark these nodes in alphabetic order.

b) (I, 6), (M, 5), (T, 6), (U, 4)

In the tree structure shown above, suppose that exactly one node represents an uncertainty point where the outcome is not controlled by either agent's strategic choice, but instead is determined by random environmental factors. Specifically, assume that from this uncertainty node, the two possible branches have probabilities $q$ and $1 - q$ of occurring. (IMPORTANT: the probabilities for the two branches can take any values where both are between 0 and 1, and together they sum to 1). For this modified scenario, consider that the lowest possible utility value in the system is zero. $p = q$ $p = 1 - q$ $q, 1-q \geq 0$ $q + (1-q) = 1$ $q, 1-q \leq 1$

c) • Suppose node $A$ is designated as the uncertainty node. Would this modification affect the expected utility value computed at the root node? If it would change, calculate the new expected value and provide reasoning for your answer. If it would not change, justify why not.

d) • Suppose node $B$ is designated as the uncertainty node. Would this modification affect the expected utility value computed at the root node? If it would change, calculate the new expected value and provide reasoning for your answer. If it would not change, justify why not.

[redacted]

C) yes, it would affect the expected value at the root node.

$E[A] = q6 + 1-q(4) = 6q + 4 - 4q = \underline{2q+4}$ q is between 0 an 1

$E[A] = 2q + 4$

So A's value ranges from; 4 to 6

node A would be chosen regardless for the root because any value 4 to 6 is greater than the other 2 nodes. However A's value may be any number 4 to 6 so the node value might change

$\Rightarrow E[\text{root node}] = 2q + 4$ since node A is selected no matter what.

d) yes, it would affect the expected value at the root node

$E[B] = 9q + 3(1-q) = 9q + 3 - 3q = 6q + 3$ if q is from 0 to 1

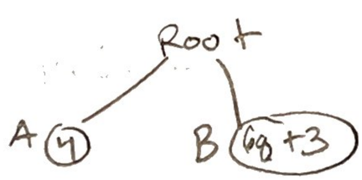
then B's value rangest from 3 to 9.

$E[B] = 6q + 3$ since B ranges from 3 to 9 it automatically is greater than node C so it only needs to compare against node A to assign root node value.

$0 - \frac{1}{6} \Rightarrow \text{root} = A$

$q\ (0 \text{ to } 1)\ \frac{1}{6} \to \frac{5}{6} \Rightarrow \text{root} = B$

if $q \geq \frac{1}{6}$ then root = node B




$E[\text{Root}] = \frac{1}{6}(4) + \frac{5}{6}(6q+3)$

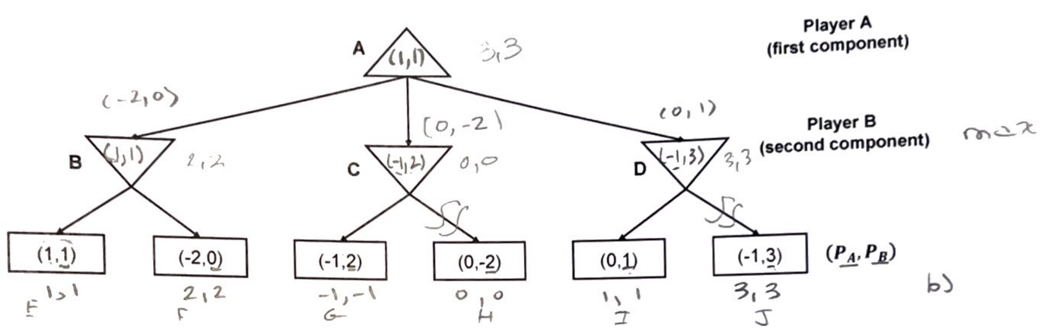
$= \frac{2}{3} + 5q + \frac{5}{2}$

$= \frac{19}{6} + 5q = E[\text{root}]$

[redacted]

6. Two rival tech companies, TechCorp (Company $A$) and InnovateLabs (Company $B$), are competing for market dominance in a new technology sector. Unlike traditional competitive scenarios where one company's gain is exactly another's loss, this market has complex dynamics where both companies can achieve different levels of success independently. A market analyst has created a decision tree showing all possible strategic moves. At each outcome, the payoffs are represented as ordered pairs $(P_A, P_B)$, where $P_A$ represents TechCorp's market share gain and $P_B$ represents InnovateLabs' market share gain. The diagram above shows the strategic landscape, with TechCorp making decisions at the top level and InnovateLabs responding at the next level.
**Important**: *TechCorp aims to maximize its own market share (the first number in each pair), while InnovateLabs aims to maximize its own market share (the second number in each pair).* player B
*Each company is solely focused on its own success metrics.*

level
0
1
2




a) • Using the generalized Minimax approach where each company optimizes for its own objective, calculate the payoff values (as ordered pairs) that propagate to each decision node in the tree. What are the final values at all internal nodes?

b) • A consultant suggests implementing $\alpha - \beta$ pruning algorithm to speed up the analysis. Explain concisely why this pruning technique cannot be applied in this market scenario where companies have independent objectives. *Hint: Consider what would happen in a simpler case where both companies always achieve identical payoffs ($P_A = P_B$ at every outcome).*

c) • If TechCorp uses this decision model to plan its strategy, but InnovateLabs makes an unexpected, suboptimal choice, could TechCorp's actual market share end up being lower than what the model predicted at the root node? Provide a brief justification for your answer. player B chooses a min

[By Kai Chen]

a) $\boxed{A: (1,1) \quad B: (1,1) \quad C: (-1,2) \quad D: (-1,3)}$

b) $\alpha$-$\beta$ pruning only works if players are working to min/max the same values and their goals are opposing. In this example players A and B are looking at different values when making their decisions, aka their objectives are independent of each other. For example in the case where payoffs are equal $P_A = P_B$ @ every outcome $\alpha$-$\beta$ pruning logic would assume that player A would try to minimize player B which is the opposite of their objective and would minimize their own payoffs too which directly contradicts their goal of also maximizing. Not zero sum, $\alpha$- ... can't remove the node that gives us the root node changing the tree and giving less than optimal game play.

c) yes, it can be lower. If on level 2 when Innovate labs is choosing between the children of B it makes suboptimal choice and picks (-2,0) instead of (1,1). then the root value would be -1 from C or D nodes which is less than original value of 1. (since options player A are now: -2, -1, -1 instead of previous: 1, -1, -1)