Homework 1

Thomas DANIEL DIA 3
AI Algorithms

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Exercise 1. As discussed in class, in 1950, Turing published a seminal paper called "Computing Machinery and Intelligence". In the paper, Turing discusses several potential objections to his test for intelligence.

Which of these objections still hold some significance today ?

Theological Objection: This objection posits that thinking is a function of the soul, which only humans possess. While less prominent in contemporary discussions, it still holds significance in debates involving religious and philosophical perspectives on artificial intelligence (AI).
"Heads in the Sand" Objection: This is the fear of the consequences of machines thinking. Today, this objection is highly relevant, especially with concerns about AI ethics, job displacement, and the potential for AI to surpass human intelligence through AGI.
Mathematical Objection: This objection, based on Gödel's incompleteness theorems, argues that there are limits to what machines can prove or compute. This remains significant, as it highlights the inherent limitations of computational systems, even as they become more advanced. The P versus NP problem is still a major unsolved problem in theoretical computer science so this objection still holds in the 21st century.
Argument from Consciousness: This objection states that machines can never be conscious or have subjective experiences. It remains a central issue in AI, particularly in discussions about whether AI can truly understand or merely simulate understanding.

Are his refutations valid ?

Turing's refutations of these objections are generally robust, especially given the context of his time. For example, his argument against the "heads in the sand" objection—that we should not let fear hinder scientific progress—resonates with ongoing debates about AI development and regulation. However, some objections, like the argument from consciousness, continue to provoke debate, as they touch on unresolved philosophical questions. in my opinion the philosophical aspect will never be solved as it is more an opinion-based question than a knowledge-based question.

Can you think of new objections that have arisen from developments since the paper was written ?

Ethical and Moral Concerns: With the rise of AI, new objections have emerged around the ethical implications of AI decision-making, bias in algorithms, and the moral status of AI entities.

Privacy and Surveillance: The use of AI in surveillance and data analysis has raised significant concerns about privacy and the potential for misuse of personal information.

Autonomy and Control: Questions about the autonomy of AI systems and the extent to which they should be allowed to make decisions independently have become more pressing.

Additionally, Turing predicts that by the year 2000, a computer would have a 30% chance of passing a five-minute Turing Test with an unskilled interrogator. What do you think a computer's chances would be today?

Today, AI systems have made significant strides, with some chatbots and conversational agents capable of convincingly mimicking human conversation in certain contexts. However, the Turing Test remains a challenging benchmark, as true understanding and context-aware conversation are still difficult for AI.

Given the advancements in natural language processing and machine learning, a computer's chances of passing a five-minute Turing Test today would likely be higher than 30%, especially with an unskilled interrogator. However, the exact percentage is hard to quantify, as it depends on the specific AI system and the context of the interaction.

Advancements in NLP: Technologies like GPT-4 and beyond have significantly improved the ability of AI to understand and generate human-like text.A fine-tuned version of GPT4 or an other big LLM model could probably pass a Turing test with an unskilled interrogator.

Contextual Understanding: While still imperfect, AI's ability to maintain context and coherence in conversation has improved.

Human-AI Interaction: Increased familiarity with AI among the general public might make it easier for AI to pass as human in casual interactions.

Exercise 2.

6	9	8
7	1	3
2	5	4

Figure 1: Initial configuration

A) Formulate this puzzle as a search problem. What are the states, actions, initial state, and goal condition?

States: A state in this puzzle represents a particular configuration of the 3×3 grid with digits 1 through 9.
Each state can be represented by a 3x3 matrix or a 1D array with 9 elements, where one of the positions is occupied by the number 9 (the sliding number).

Actions: The actions define how the sliding number (9) can move.
Since the 9 can move up, down, left, or right (if not blocked by the edges of the grid), the possible actions are:

- Up: Move the number 9 up (swap 9 with the number above it).
- Down: Move the number 9 down (swap 9 with the number below it).
- Left: Move the number 9 to the left (swap 9 with the number to its left).
- Right: Move the number 9 to the right (swap 9 with the number to its right).

Initial state: The initial state is the starting configuration of the puzzle, as described in the problem.

Goal condition: The goal condition is that the grid forms a magic square, where: The sum of the numbers in each row, column, and both diagonals equals 15.

4	3	8
9	5	1
2	7	6

Goal state example

For example:

Row sums: 4 + 3 + 8 = 15, 9 + 5 + 1 = 15, 2 + 7 + 6 = 15.
Column sums: 4 + 9 + 2 = 15, 3 + 5 + 7 = 15, 8 + 1 + 6 = 15.
Diagonal sums: 4 + 5 + 6 = 15, 2 + 5 + 8 = 15.

B) Determine whether the state space is represented as a graph or a tree.

In this puzzle, the number 9 can move around the grid in different directions (up, down, left, or right). However, since the movements are reversible (i.e., you can move 9 back to a position it previously occupied), this creates cycles in the state space. For example, if 9 moves up, then moves back down, the puzzle returns to the same configuration it was in before the first move. This indicates that the state space contains repeated states, which are a hallmark of graph structures (as opposed to trees, where each node is unique).

There can be multiple ways to reach the same state in the puzzle. For instance, moving 9 right and then left brings it back to its original position, which could also be reached by different sequences of moves. This means that different paths (sequences of moves) can lead to the same state (grid configuration), which again is a characteristic of a graph structure rather than a tree, where nodes are reached by a unique path.

In a graph, each node represents a state (a specific grid configuration), and each edge represents an action (a valid movement of 9). The edges between nodes do not imply a strict hierarchy, and the same state can be reached from different previous states, forming a graph with cycles and multiple paths between nodes.

C) How large is the state space?

As mentioned in question B, the state space (i.e graph representation) contains all possible grids with the number ranging from 1 to 9. The total number of grids is : $9! = 362880$. However this is not the state space as some initial grids are not solvable (this is due to group theory). The real number of solvable grids is $9!/2 = 181440$.

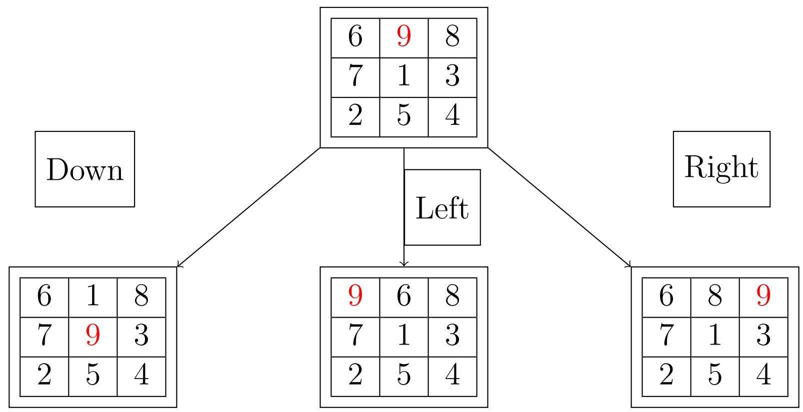
Source:`https://en.wikipedia.org/wiki/15_puzzle`

D) What is the maximum branching factor for this problem? Provide justification.

The branching factor refers to the number of possible actions (moves) that can be taken from any given state. In this puzzle, the number of possible moves is determined by the current position of the sliding number (9) within the 3x3 grid. There are four possible moves in total: up, down, left, and right. However, the actual number of valid moves depends on the position of the number 9 on the grid.

-Top and bottom corners : branching factor is 2
-Edges : branching factor is 3
-Middle square: branching factor is 4
The maximum branching factor is 4.

E) Draw a portion of the search graph resulting from Breadth-First Search (BFS) algorithm. Label the nodes in the order in which they are expanded.



End of the first step of BFS.

If we start the next phase of the BFS starting from the precedent DOWN position we get the following matrix using a down move again :

6	1	8
7	5	3
2	9	4

Goal state found through BFS.

Labelling the node expansion :

Expand node	**List of nodes**
	node 9
Initial grid not goal state	nodes 1,6,8
Grid resulting from down action (not goal)	nodes 6,8,5,7,3
Grid resulting from first left action(not goal)	nodes 8,5,7,3
Grid resulting from first right action(not goal)	nodes 5,7,3
Grid resulting from second down action(goal state found)	

F) Draw a portion of the graph search generated by the Depth-First Search (DFS) algorithm and label the states in the order they are expanded.

6	9	8
7	1	3
2	5	4

$\downarrow$ Down

6	1	8
7	9	3
2	5	4

$\downarrow$ Down

6	1	8
7	5	3
2	9	4

Labelling the node expansion :

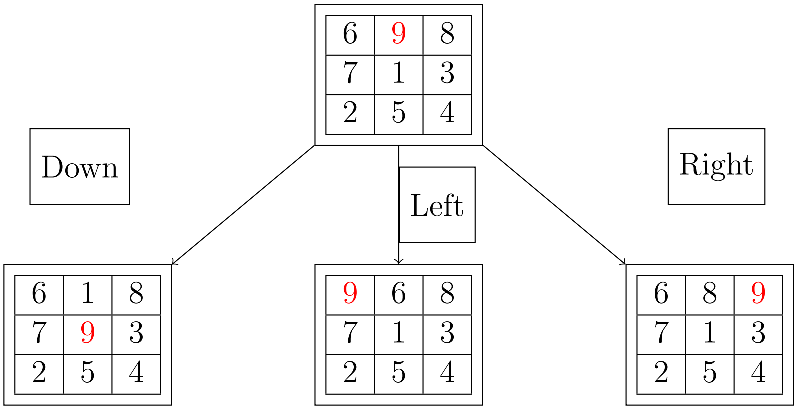
Expand node	**List of nodes**
	node 9
Initial grid not goal state	nodes 1,6,8
Grid resulting from down action (not goal)	nodes 5,7,3,6,8
Grid resulting from second down action(goal state found)	

G) Draw a portion of the graph search generated by the Iterative Deepening Search (IDS) algorithm and label the order in which each state is expanded.

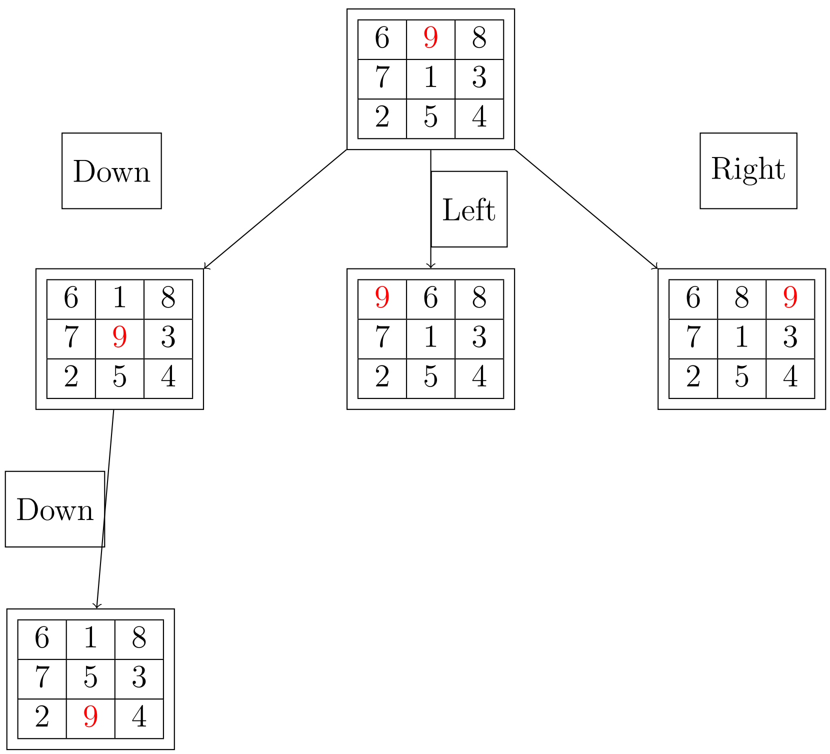
Depth 0 :

6	9	8
7	1	3
2	5	4

Depth 1 :



Depth 2 :



Last DOWN move is giving us the goal state

Depth 1 expansion of nodes :

Expand node	**List of nodes**
	node 9
Initial grid not goal state	nodes 1,6,8
Grid resulting from down action (not goal)	nodes 6,8
Grid resulting from first left action(not goal)	nodes 8
Grid resulting from first right action(not goal)	

H) What are the advantages and disadvantages of Breadth-First Search and Iterative Deepening Search for this problem? Would Depth-First Search with no limit be a better or worse approach? Why?

Breadth-First Search (BFS):

Advantages: Guaranteed to find the shortest path in terms of the number of moves. Complete: will find a solution if one exists.
Disadvantages: Can consume a lot of memory due to storing all generated nodes at the current depth level. May take longer to find a solution compared to other methods in some scenarios.

Iterative Deepening Search (IDS):

Advantages: Combines the space efficiency of DFS with the completeness of BFS. Uses a minimal amount of memory compared to BFS since it only stores nodes in the current depth limit.
Disadvantages: The repeated exploration of states can lead to more node expansions, potentially making it slower than BFS in terms of time.

Depth-First Search (DFS) with No Limit:

Advantages: Space-efficient as it only needs to store nodes along the current path. Can be faster in some cases since it may quickly reach a solution deep in the search space.
Disadvantages: Not complete: may get stuck in infinite loops or explore deep paths that do not lead to a solution. Can take a long time if it explores deep states without finding a solution.

I) Propose a non-trivial admissible heuristic for solving this problem.

A suitable admissible heuristic for the Sliding Magic Square could be:
Heuristic: Count of misplaced numbers.
Description: Count how many numbers (1 to 8) are not in their goal positions. Since the magic square configuration is unique, this heuristic is straightforward and provides a clear metric for how far the current state is from the goal state. It is admissible because it never overestimates the number of moves required to reach the goal. Using this heuristic helps

prioritize states that are closer to the goal configuration, guiding the search process more effectively.
In a sense, it would give a type of 'entropy' measure in the grid. It would indicate how much the grid is shuffled and how closed it is to a solution (goal state being the lowest entropy).

Exercise 3. The solution can be found in the .ipynb file in the zip file. All questions are answered in the notebook