



University of Puerto Rico  
Department of Electrical and Computer Engineering  
ICOM5015 Artificial Intelligence



# Hill Climbing Applications and Simulated Annealing

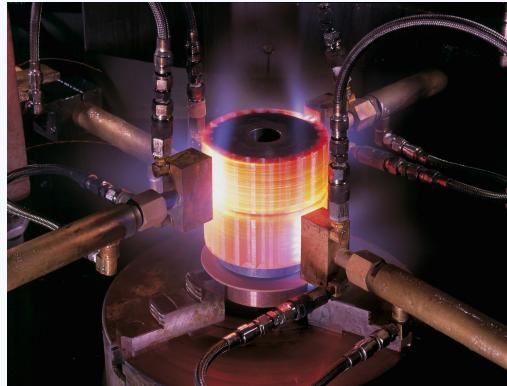
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Date: March 26, 2025

# Agenda

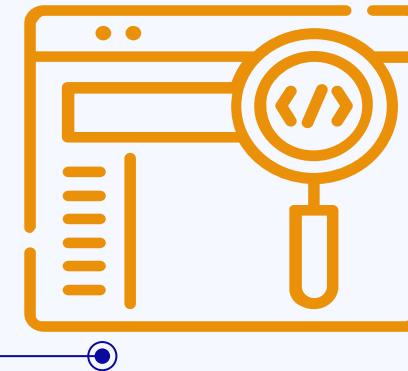
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# 01

# Purpose of experiment

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- Study the performance of the Hill Climbing Search Algorithm utilizing different implementations like steepest-ascent, first-choice, and random restart.
- Study the performance of Simulated Annealing search algorithm.
- All these algorithms were tested and their efficiencies were compared by how they were able to solve the 8 puzzle problem and the 8 queen problem.



02

# Key questions and hypothesis



# How effective are different approaches of hill climbing and annealing given the same problems?

- Are there a difference between the different subsections of the algorithm hill climbing?
- Is annealing better than hill climbing in all problem formulations?
- What is the efficiency of the different subsections of the hill climbing algorithm and annealing?

Hypothesis: Simulated annealing will fare better at solving the given tests than hill climbing as it is not constrained in only doing the most optimal move.



# 03

# Concepts



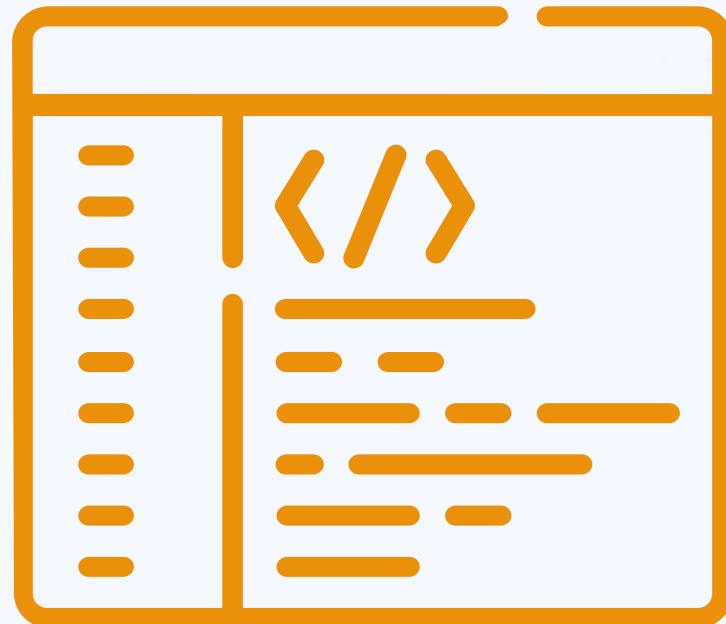
# Experimental concepts

## Platform

Python: Programming language of high level. Emphasizes code readability with the use of indentation.

## Subjects

- Steepest-Ascent Hill Climbing Search Algorithm
- First-choice Hill Climbing Search Algorithm
- Random Restart Hill Climbing Search Algorithm
- Simulated Annealing Search Algorithm



# Experimental concepts

Eight Puzzle Problem- Place the tiles 8 numbered in a 3 by 3 grid in a specified order with the least amount of moves possible.

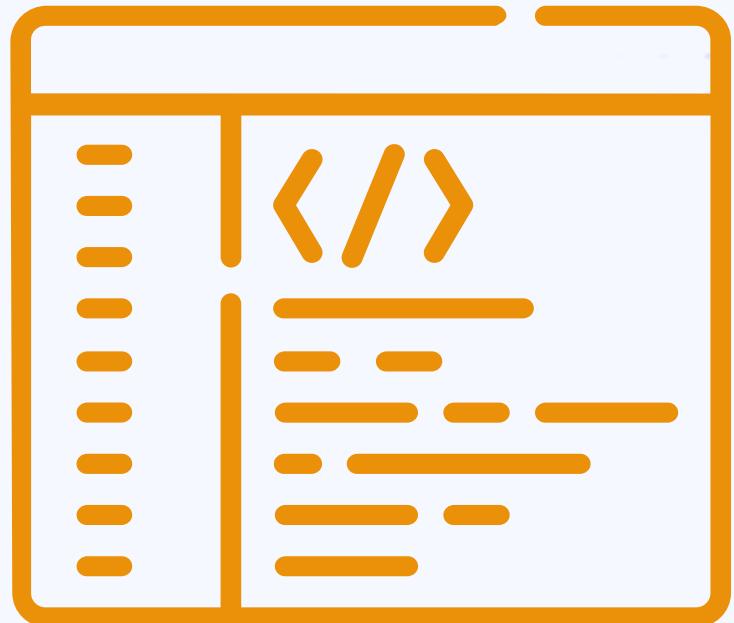
Eight Queen Problem- Place 8 queens in a chess board, one for each column of the board, and change their positions in such a way that no queen attacks each other directly or indirectly.

## Measure

Manhattan Heuristic function- Uses the Manhattan distance to estimate the cost to reach a goal state from the current state.

Manhattan distance - Sum of the absolute difference of the coordinates.

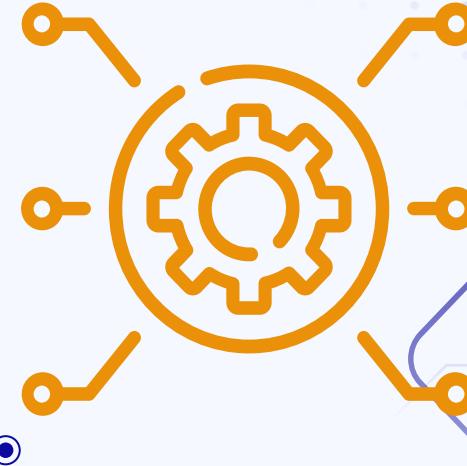
- Attacking Pairs Heuristic Function – Counts the # of attacking queen pairs (directly or indirectly).



# 04

# Experiments

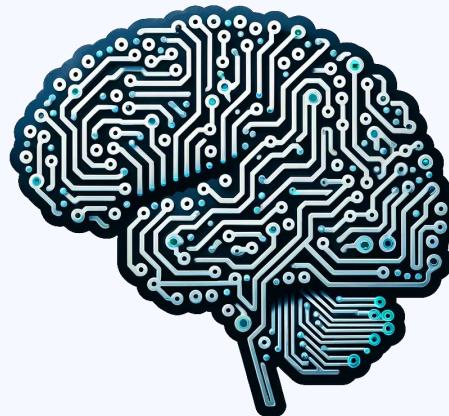
# set up.



# Tools and Resources Utilized

The following tools and resources were used:

- **Aimacode Repository:** The core repository containing foundational code and algorithms for the problem.
- **For Problem 4.4:** Simulated annealing and subsets for the hill climbing algorithm were created using the base foundation of the Aimacode Repository for the given problems being instances of 8 puzzle and 8 queens problems. The created subsets include steepest ascent, first choice ,and random restart for hill climbing.



# Method for comparing

## Criteria Used for Comparison:

- **Performance:** If the algorithm found the optimal solution to the problem or how close it was to find the optimal solution and what is the percentage of success.
- **Efficiency:** Evaluates the amount of moves it took to find the solution, if it found it.

In **Problem 4.4**, the same criteria was used adding to the fact that a direct comparison was made with the number of successful attempts against the failures.



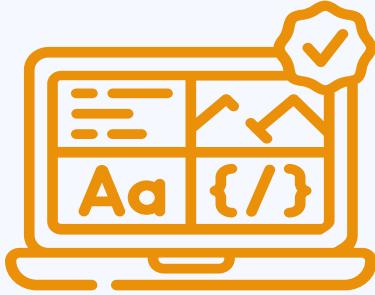
# Method for graph creation

How the Data for the graph was collected and used.

- **For exercise 4.4:** The information was collected after the algorithm finished running.
- The collected data was compared with the goal state of the problem. The solution gathered, if found to be the same, was added to a success list that counted how many instances actually succeeded the problem.
- The cost is put in a scatter plot with its optimal cost as the x axis and its actual cost as the y axis.



05



# Information.

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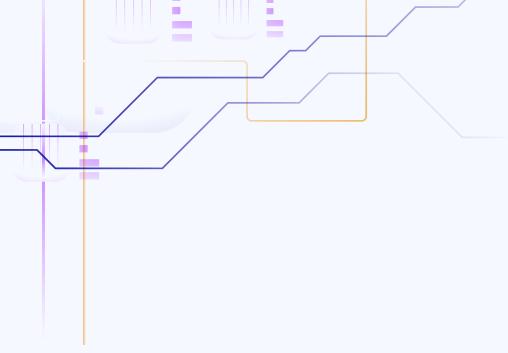
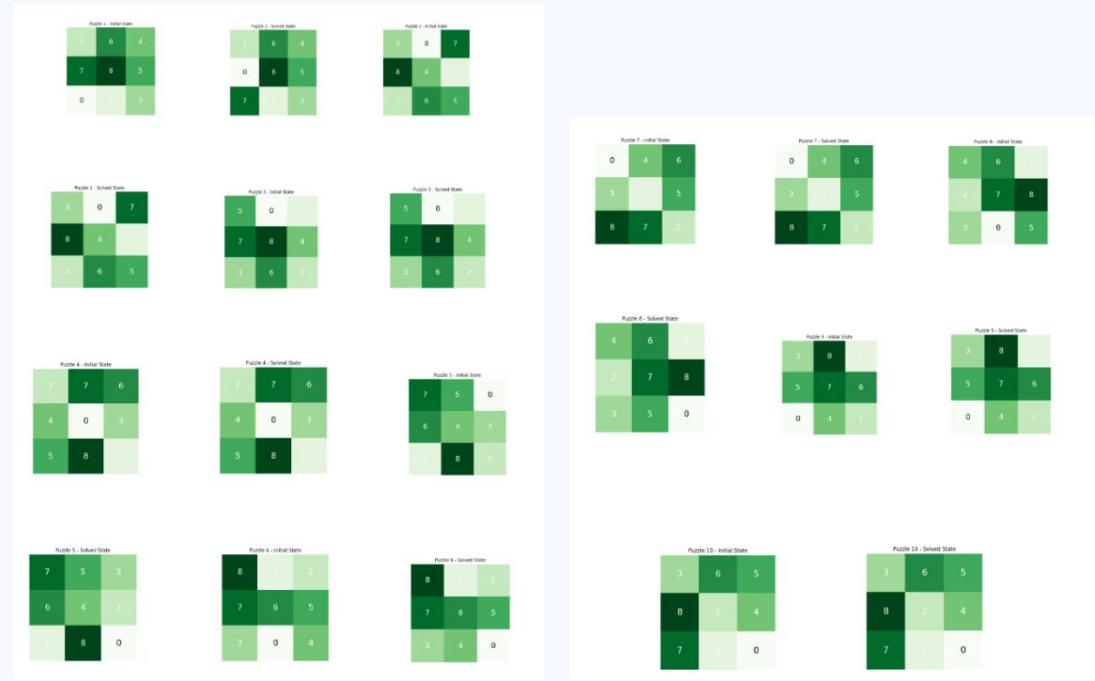
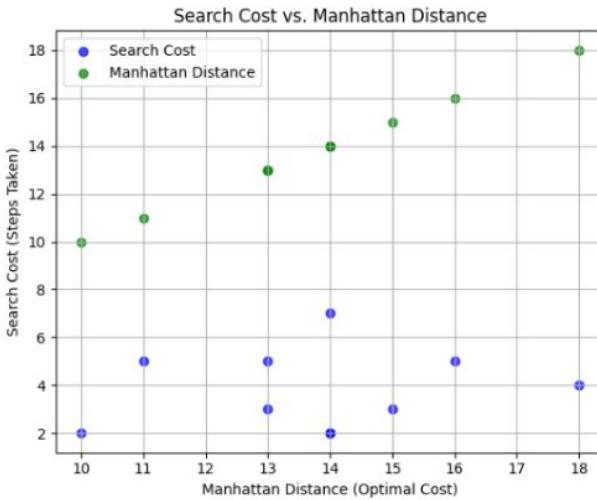
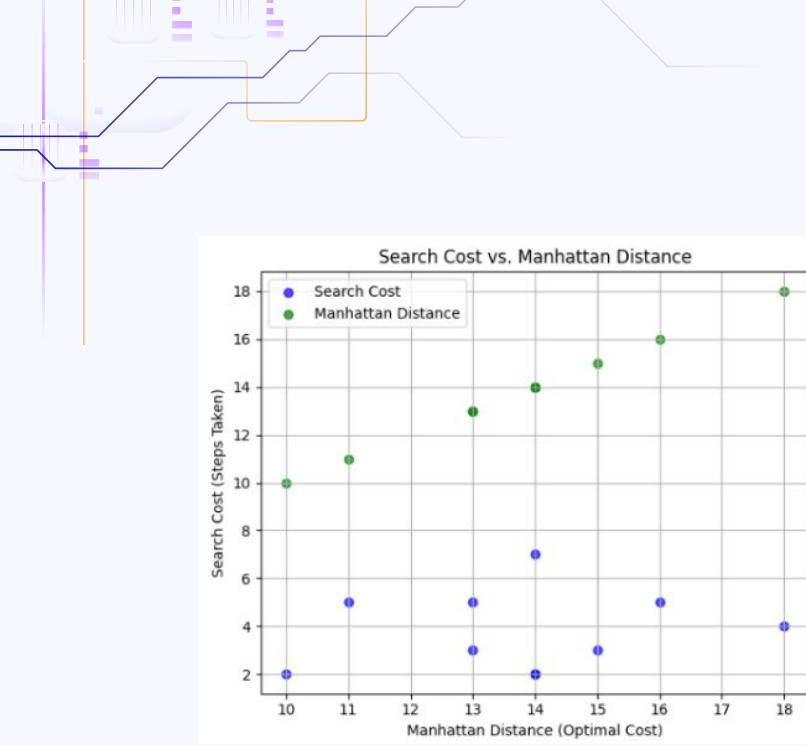
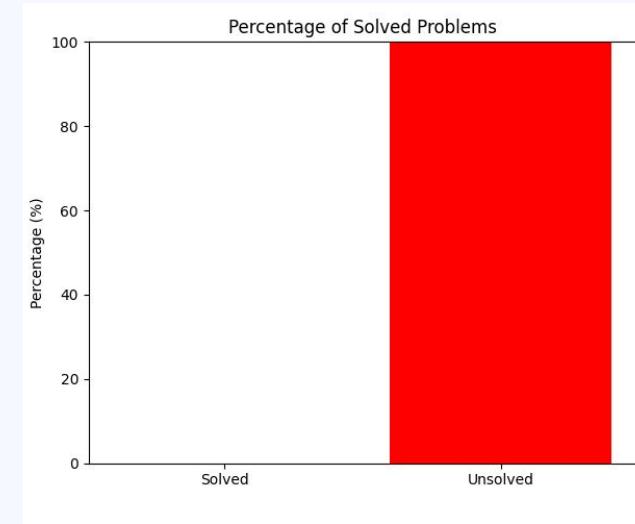


Figure 1. Results for 8 puzzle utilizing Steepest Ascent Hill Climbing





Graph 1. Search Cost vs Manhattan Distance (Optimal Cost) of Steepest Ascent Hill Climbing in 8 puzzle



Graph 2. Percentage of solved and unsolved puzzles utilizing the Steepest Ascent Hill Climbing for the 8 puzzle

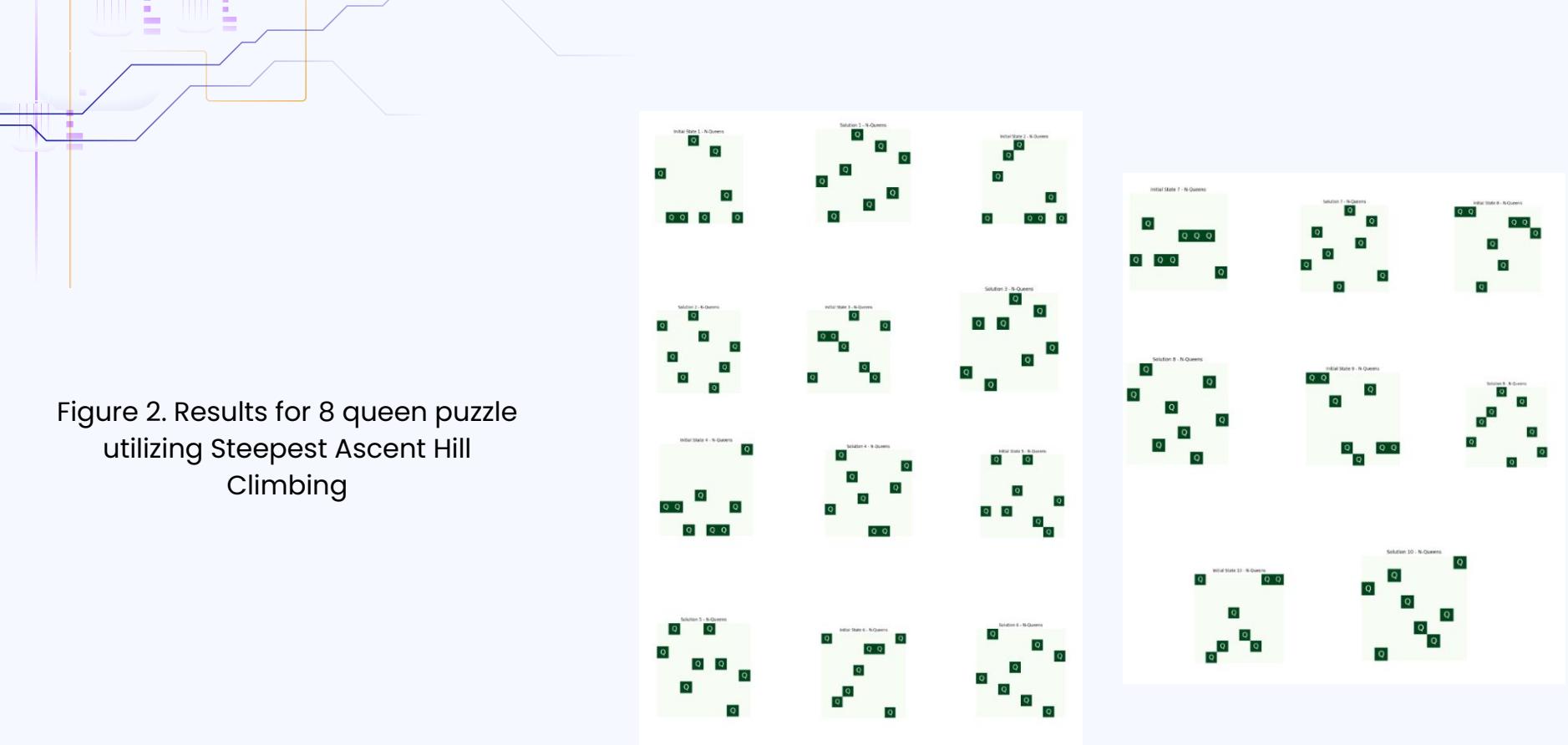
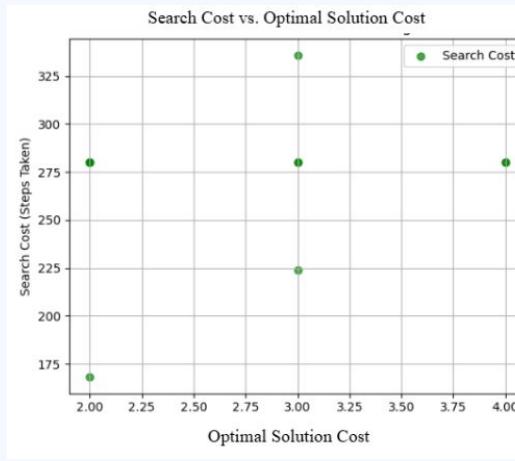
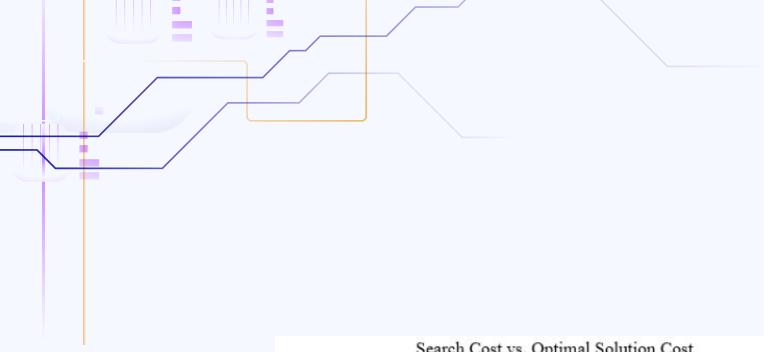
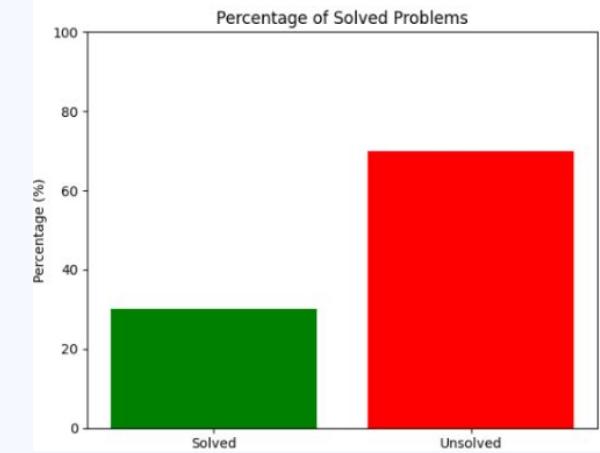


Figure 2. Results for 8 queen puzzle utilizing Steepest Ascent Hill Climbing

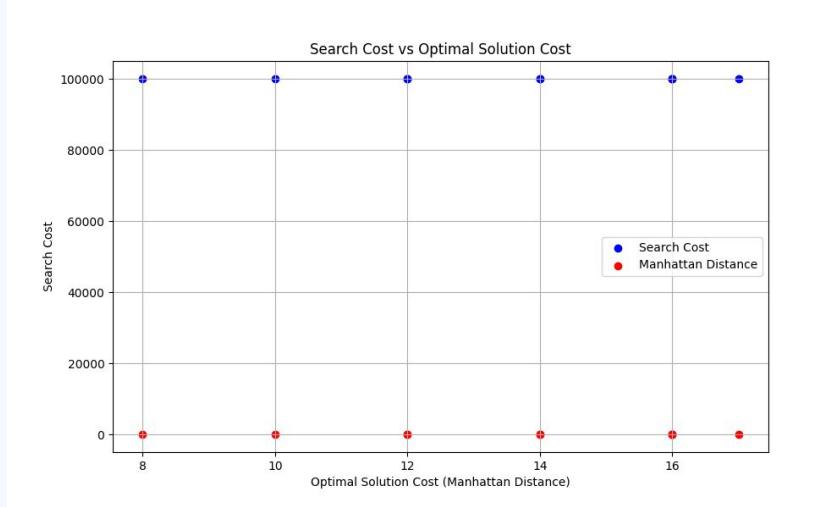
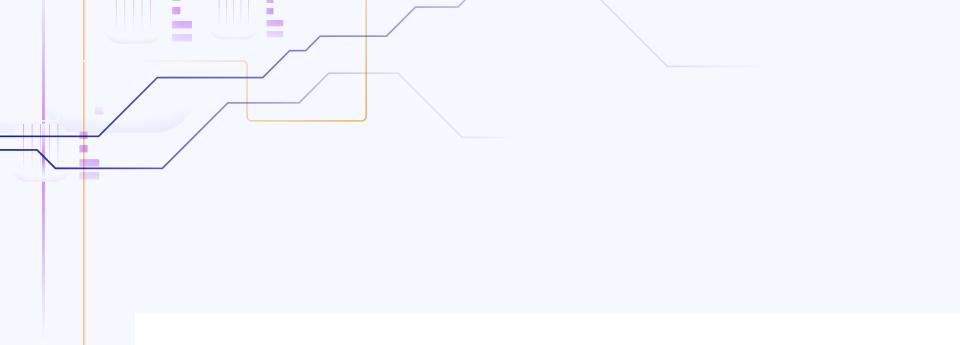


Graph 3. Search Cost vs Manhattan Distance (Optimal Cost) of Steepest Ascent Hill Climbing in 8 queen puzzle

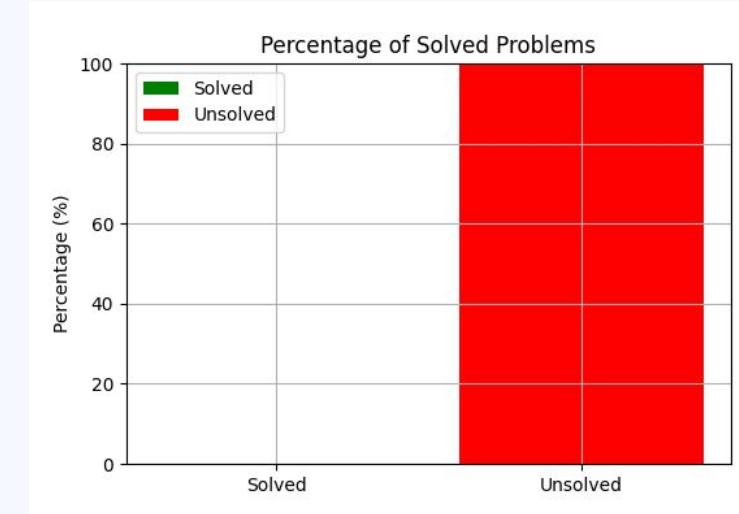


Graph 4. Percentage of solved and unsolved puzzles utilizing the Steepest Ascent Hill Climbing for the 8 queen problem





Graph 5. Search Cost vs Manhattan Distance (Optimal Solution Cost) of First Choice Hill Climbing in 8 puzzle



Graph 6. Percentage of solved and unsolved puzzles utilizing the First Choice Hill Climbing for the 8 puzzle

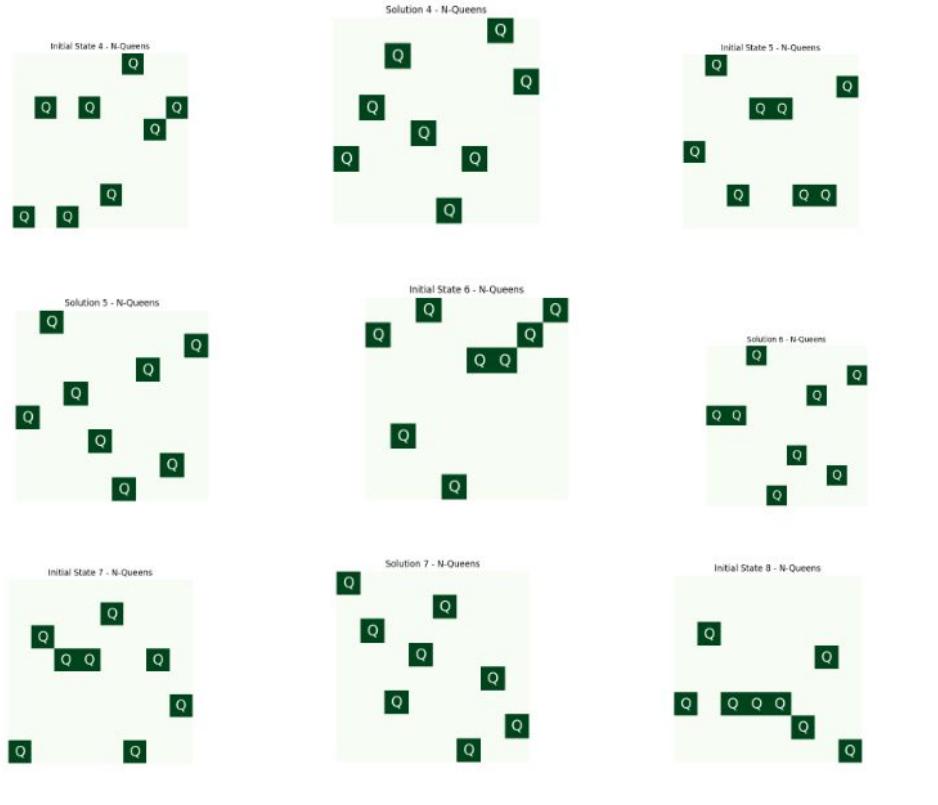
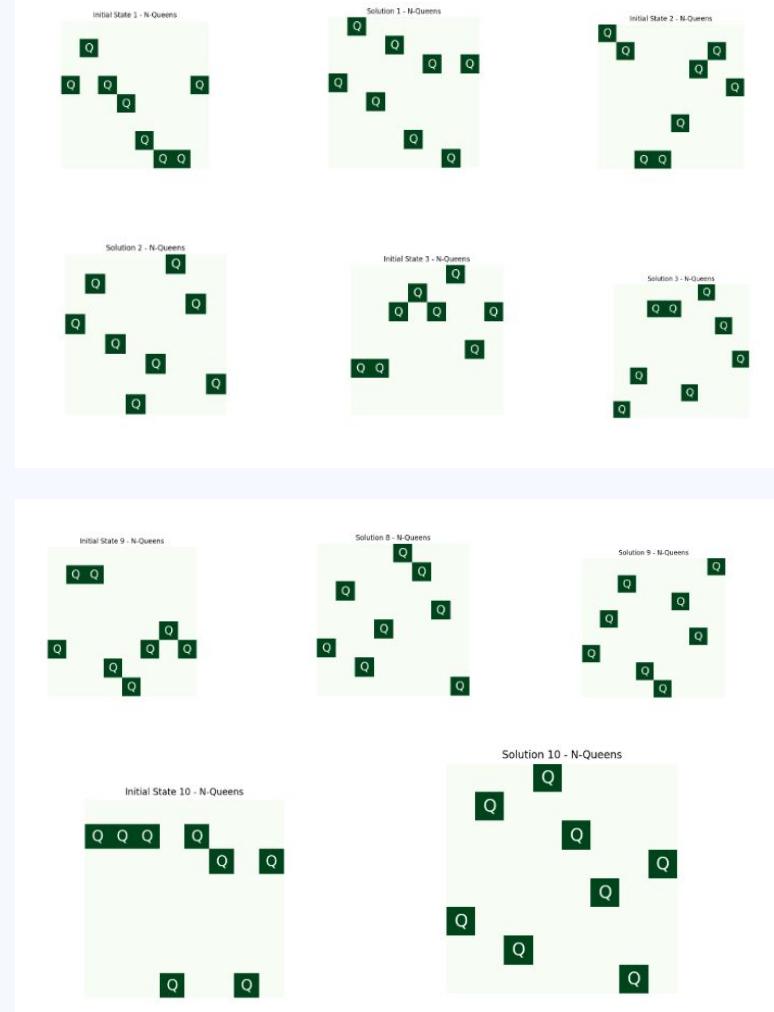
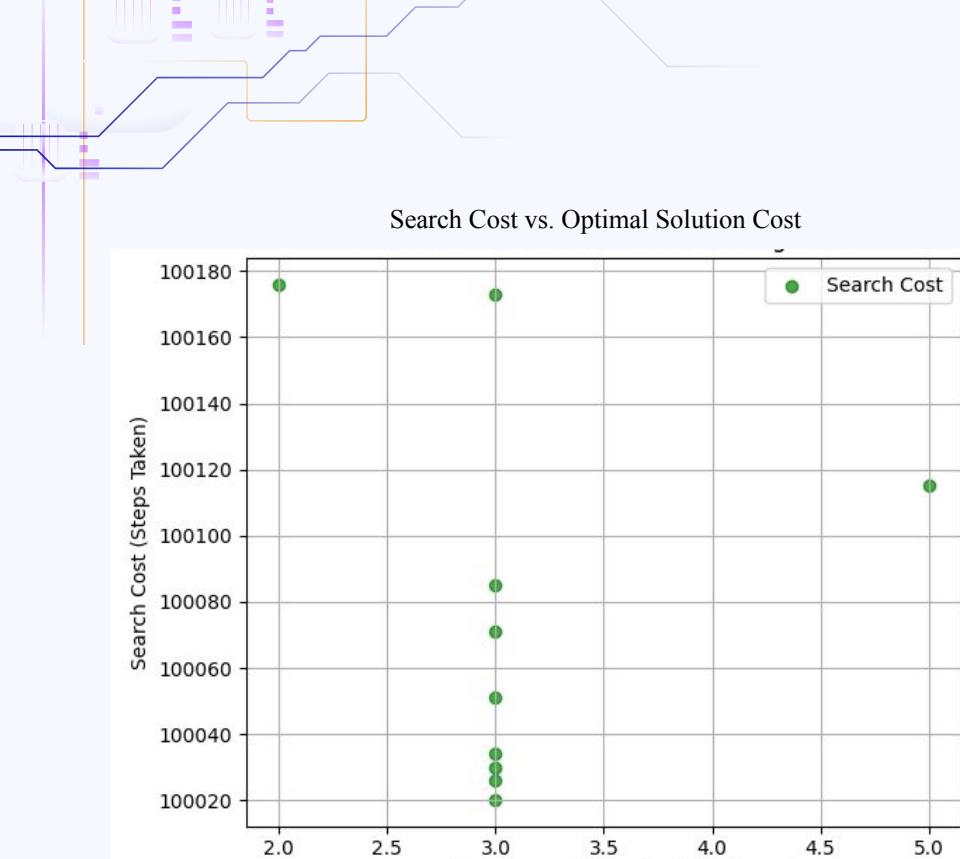
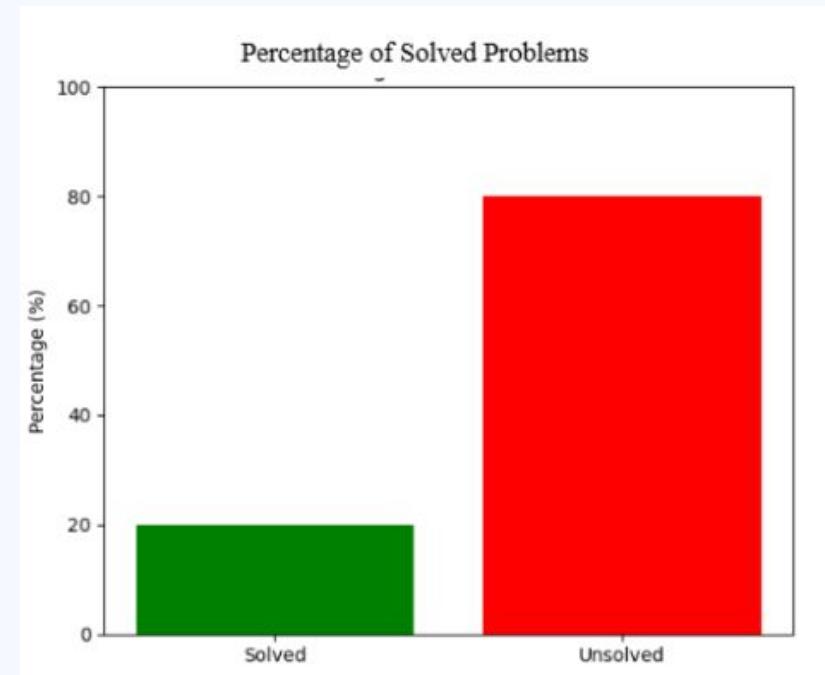


Figure 4. Results for 8 queen puzzle utilizing First-Choice Hill Climbing





Optimal Solution Cost  
Graph 7. Search Cost vs Optimal Solution Cost of First Choice Hill Climbing in 8 queen problem



Graph 8. Percentage of solved and unsolved puzzles utilizing the First Choice Hill Climbing for the 8 queen problem

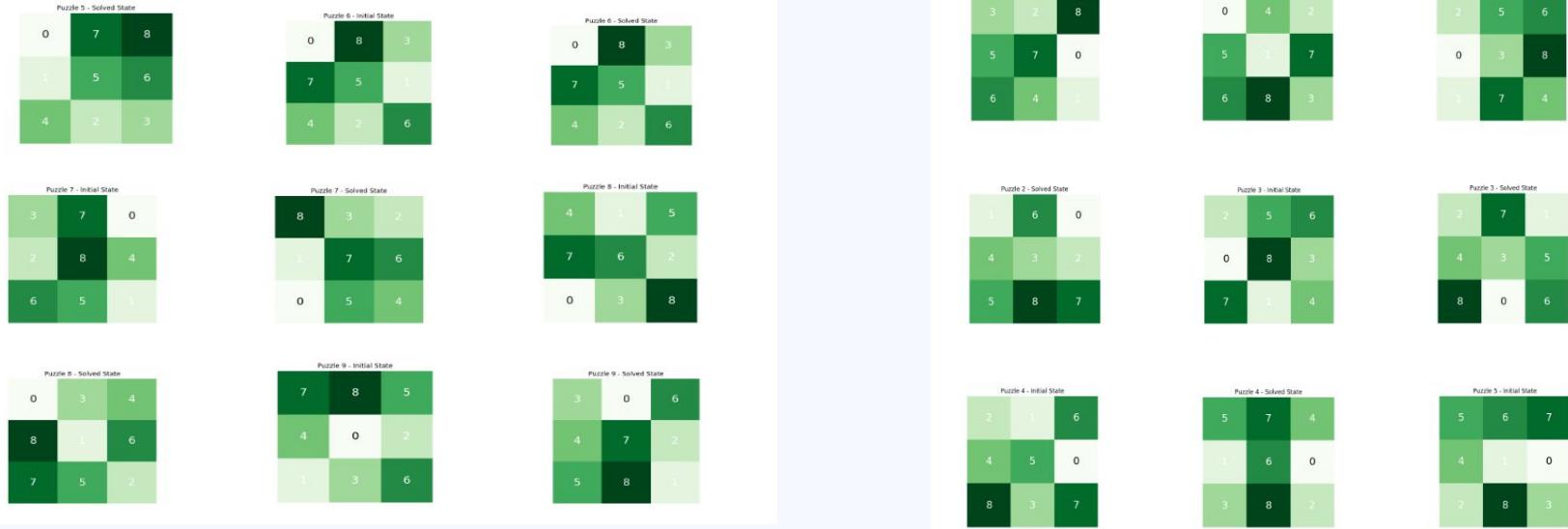
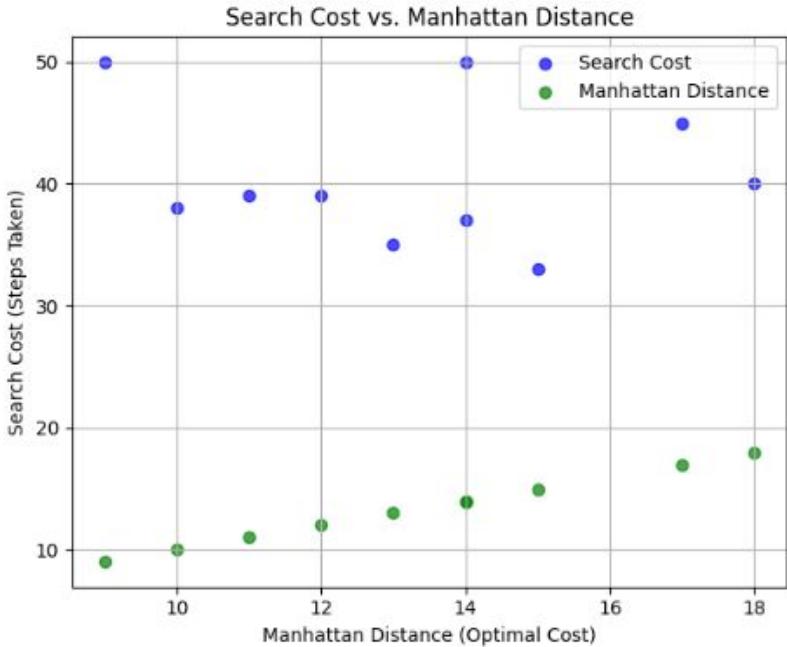
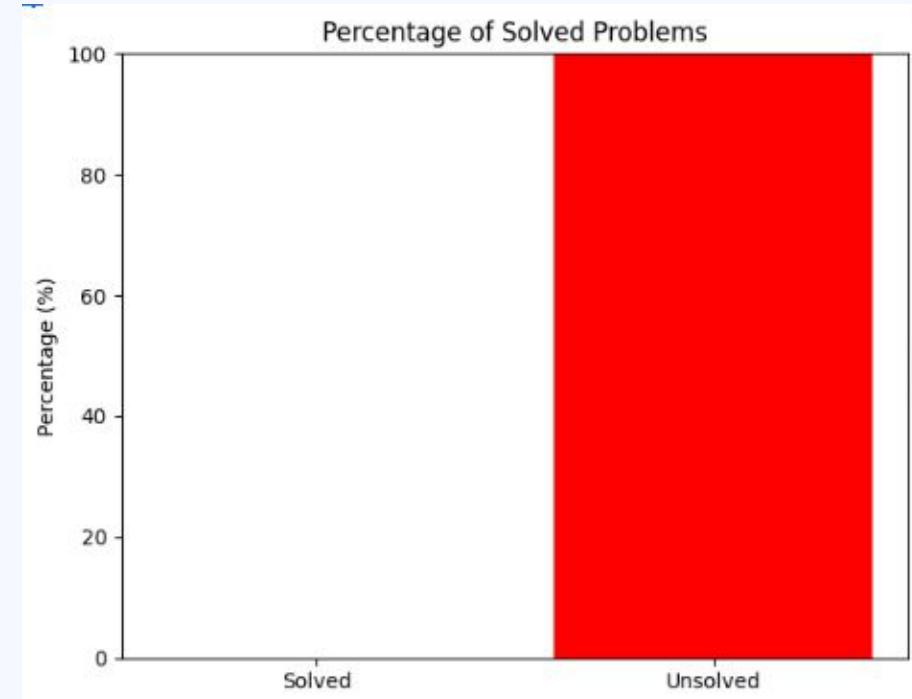


Figure 5. Results for 8 puzzle utilizing Random restart Hill Climbing





Graph 9. Search Cost vs Manhattan Distance (Optimal Solution Cost) of Random restart Hill Climbing in 8 puzzle



Graph 10. Percentage of solved and unsolved puzzles utilizing the Random Restart Hill Climbing for the 8 puzzle

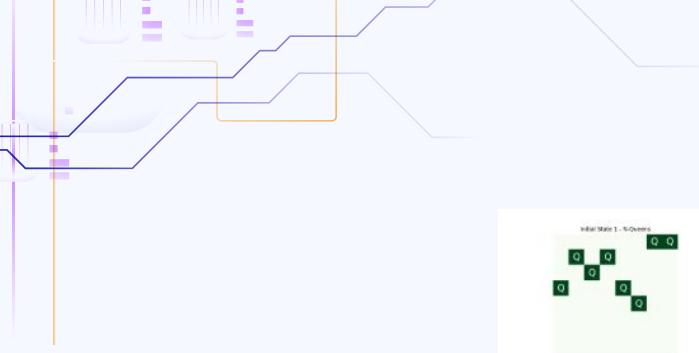
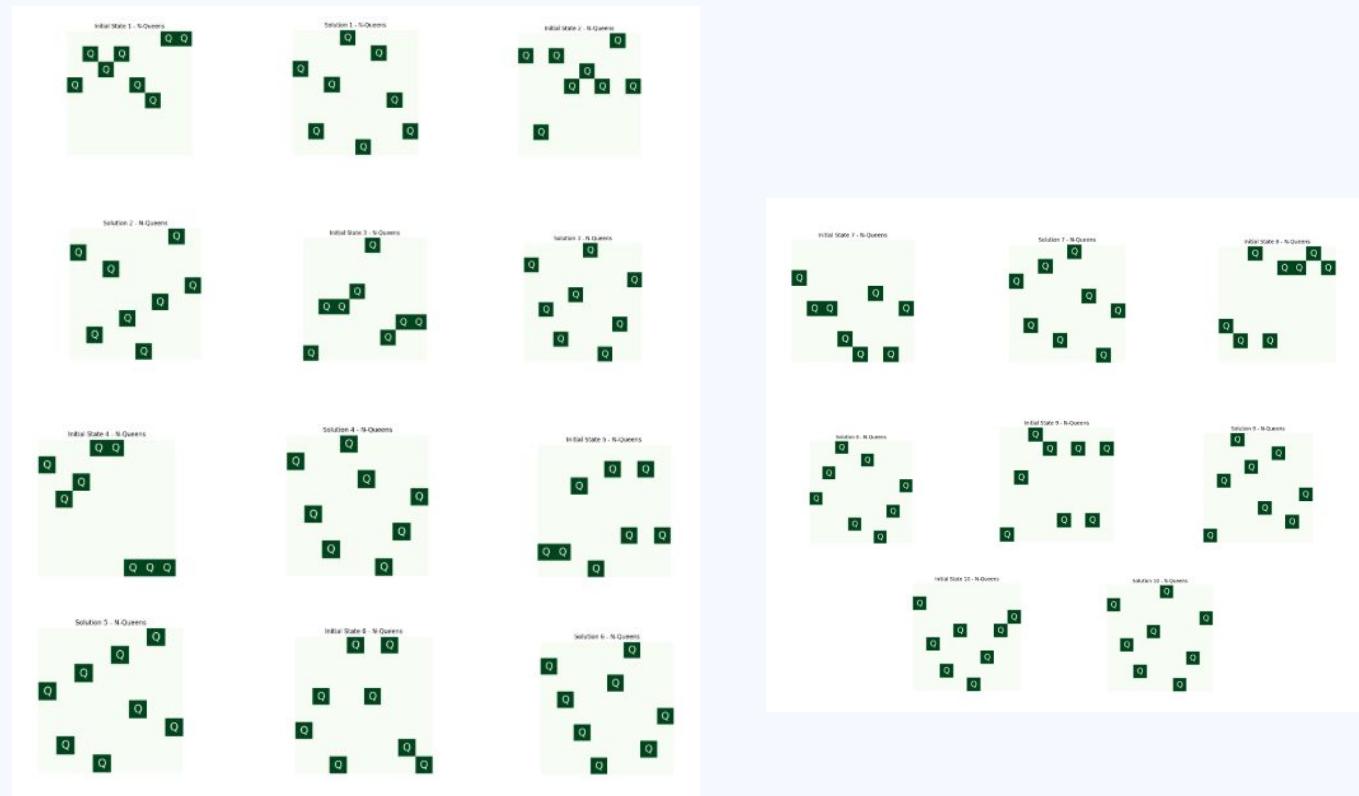
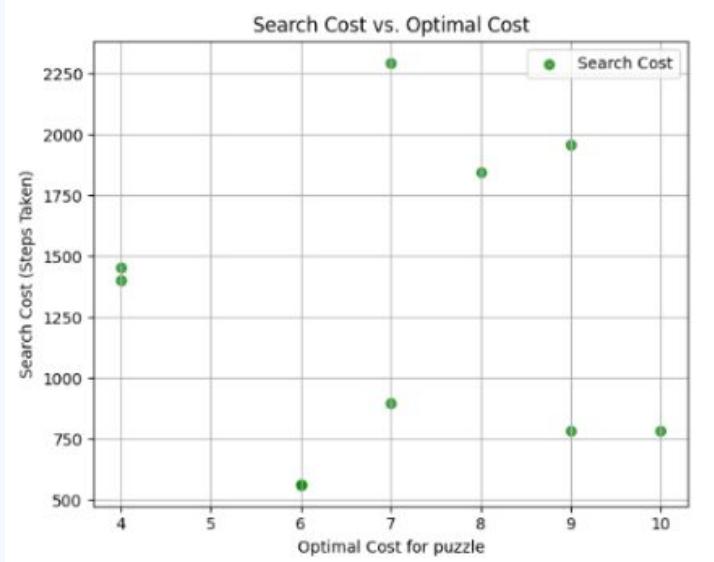
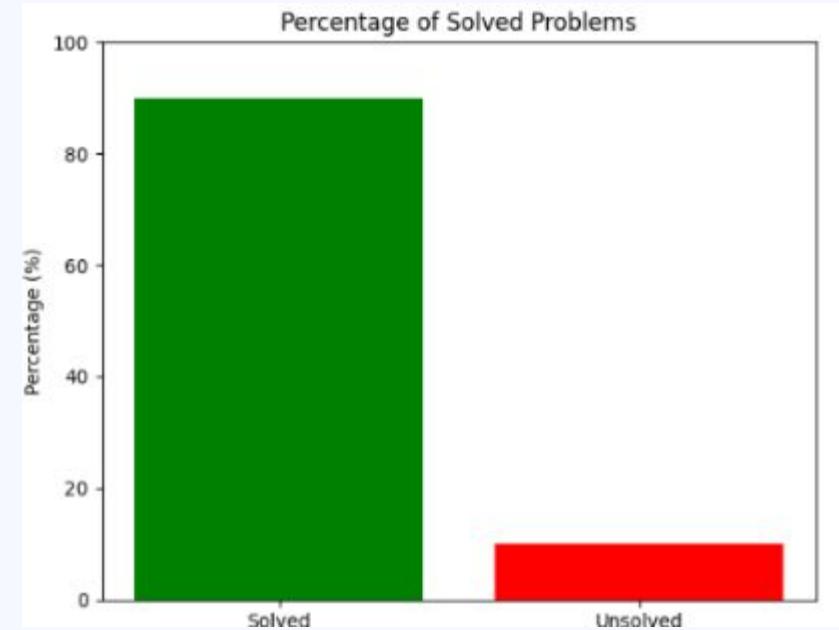


Figure 6: Results for 8 queen puzzle utilizing Random Restart Hill Climbing





Graph 11. Search Cost vs Optimal Solution Cost of First Choice Hill Climbing in 8 queen problem



Graph 12. Percentage of solved and unsolved puzzles utilizing the Random restart Hill Climbing for the 8 queen problem



Figure 7. Results for 8-puzzle utilizing Simulated Annealing

Puzzle 1-Initial State	Puzzle 1-Solution State	Puzzle 2-Initial State	Puzzle 2- Solution State
2 3 6	4 7 2	1 5 2	3      8
1 5 8	5 1 8	4 3 6	5 1 2
4 7	6      3	7 8	4 7 6

Puzzle 3-Initial State	Puzzle 3-Solution State	Puzzle 4-Initial State	Puzzle 4- Solution State
2      3	5 6 3	1 3 6	6 7 3
1 4 6	2 1	7 2	1 5
7 5 8	4 8 7	5 4 8	4 8 2

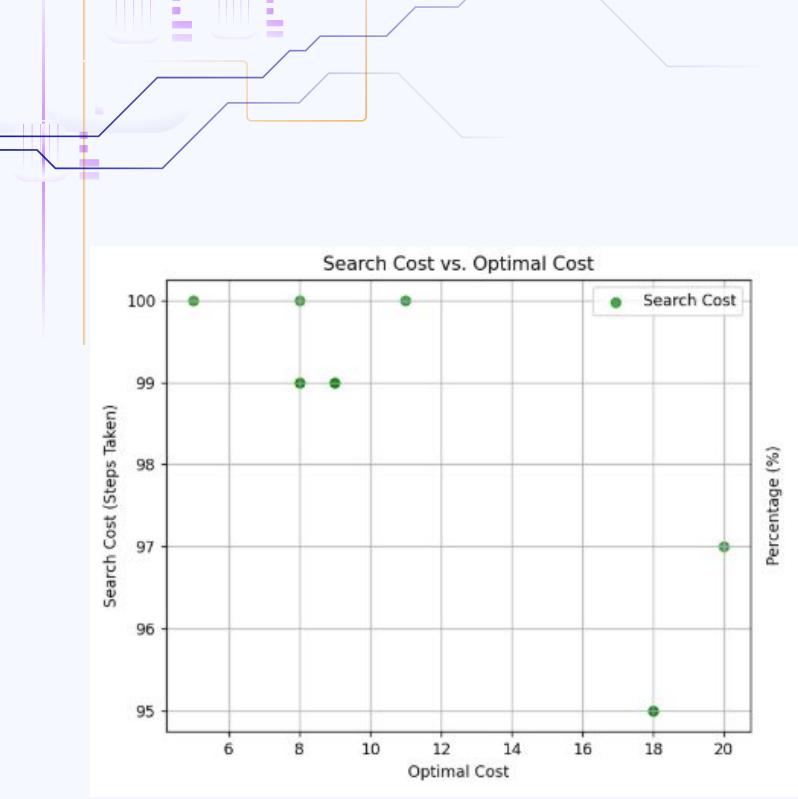
Puzzle 5-Initial State	Puzzle 5-Solution State	Puzzle 6-Initial State	Puzzle 6- Solution State
4 5	2 4 5	2 5 3	1 3 5
7 6 1	7 6	1 7 6	2 7 6
3 2 8	3 8 1	4 8	4 8

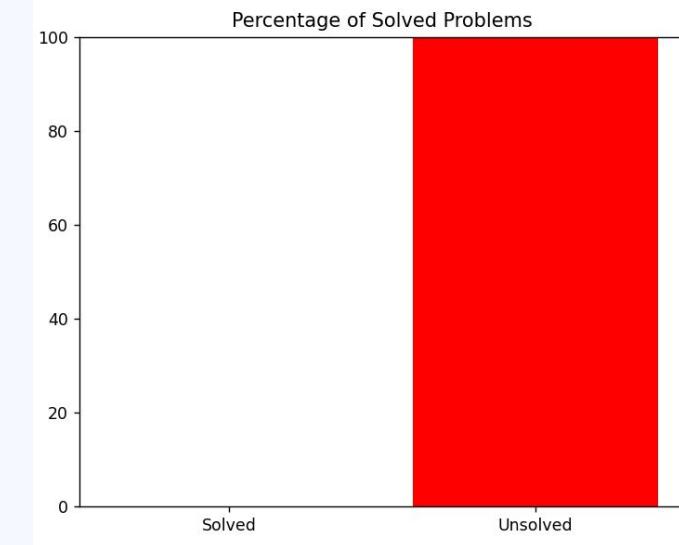
Puzzle 7-Initial State	Puzzle 7-Solution State	Puzzle 8-Initial State	Puzzle 8- Solution State
4 1 2	3 4 6	3 4 2	7      2
5 3 6	2      5	1 7 6	4 3 5
7      8	7 1 8	5 8	1 8 6

Puzzle 9-Initial State	Puzzle 9-Solution State	Puzzle 10-Initial State	Puzzle 10- Solution State
5 1 3	6 3 4	8 3	7 2 5
4 2 6	2 7 1	2 5 6	1 3 8
7      8	5 8	7 1 4	4      6



Graph 13. Search Cost vs Optimal Solution Cost of Simulated Annealing in 8-puzzle



Graph 14. Percentage of solved and unsolved puzzles utilizing Simulated Annealing for 8-puzzle

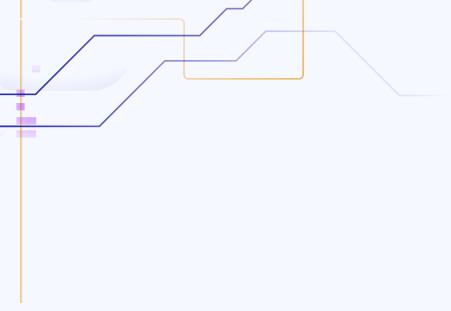
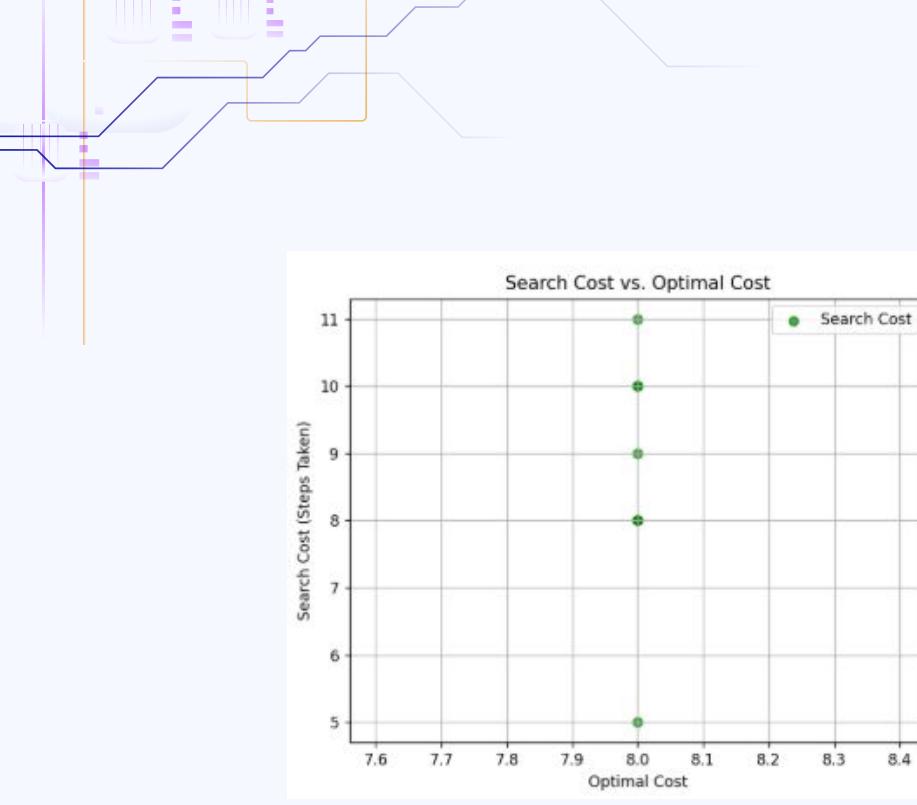
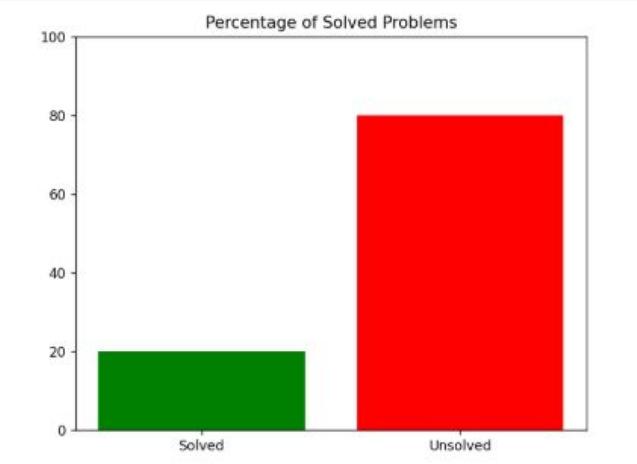


Figure 8: Results for 8-queen puzzle utilizing Simulated Annealing without an initial state





Graph 15. Search Cost vs Optimal Solution Cost of Simulated Annealing in 8-queen problem (Without initial state)



Graph 16. Percentage of solved and unsolved puzzles utilizing Simulated Annealing for 8-queen problem (Without initial state)

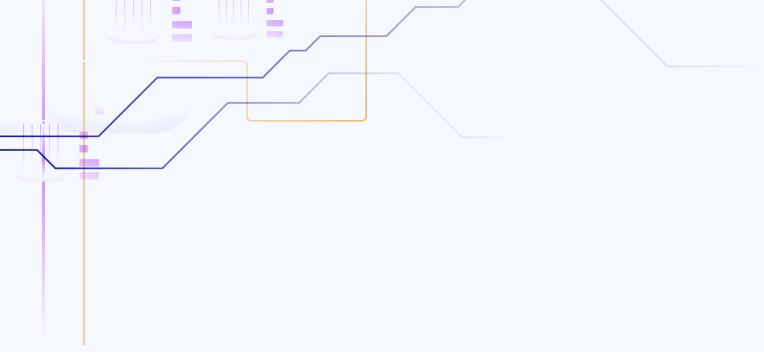
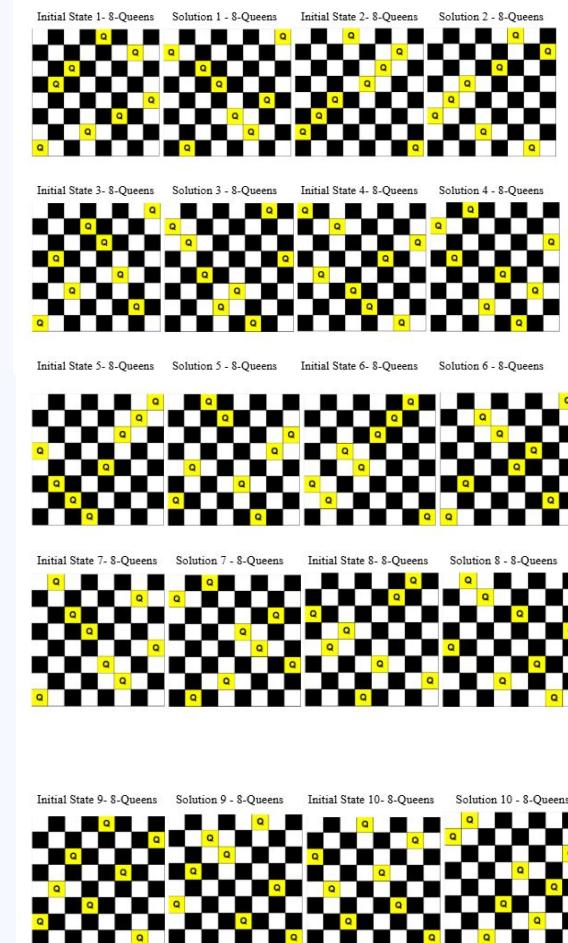
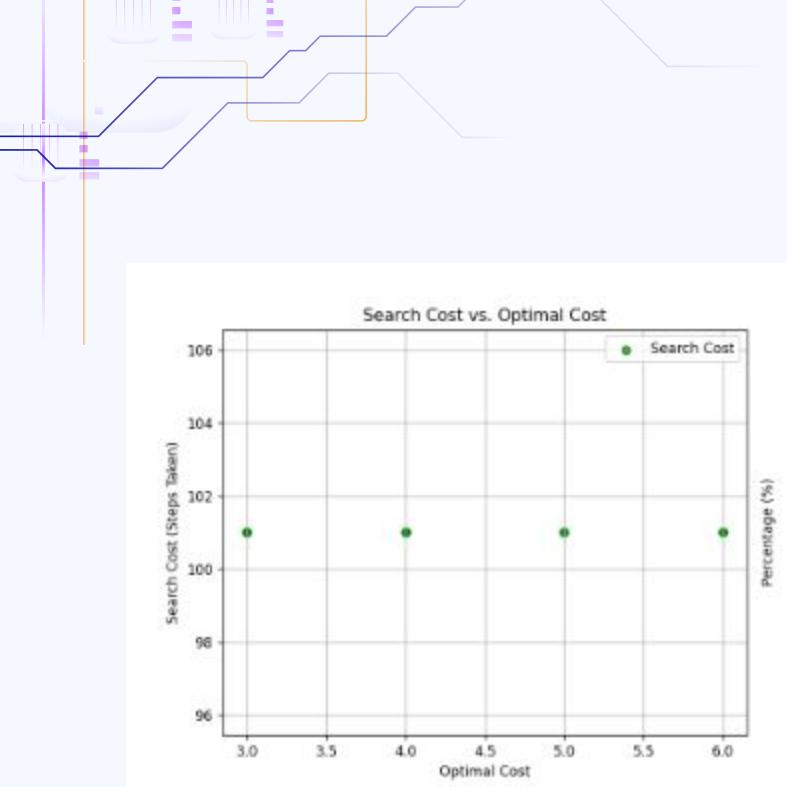
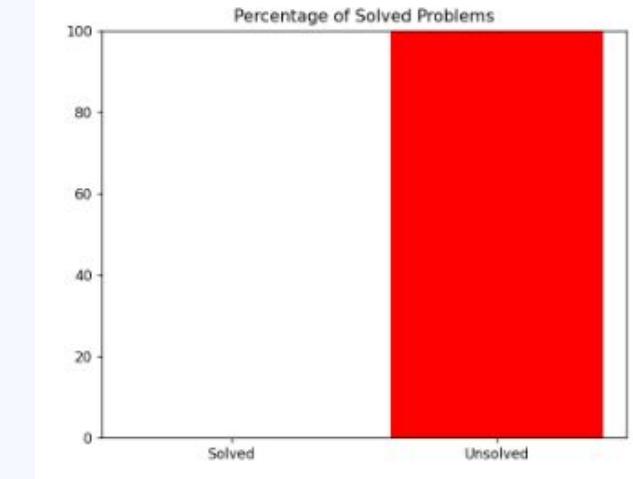


Figure 9: Results for 8-queen puzzle utilizing Simulated Annealing with an initial state





Graph 17. Search Cost vs Optimal Solution Cost of Simulated Annealing in 8-queen problem (With initial state)



Graph 18. Percentage of solved and unsolved puzzles utilizing Simulated Annealing for 8-queen problem (With initial state)

06

# Conclusion and Lessons

Learned.



# Conclusions and Lessons Learned

## 01 — Hill Climbing Limitations

Search algorithms are often used in AI applications to solve complex problems. Hill climbing offers a fair amount of robustness as it always chooses a state that improves the current one. However, it has noticeable limitations that stop it from consistently finding the solution to a problem. The lack of complexity in its design often leads it to get stuck in local maxima with no way of achieving the goal.

## 02 — Complexity and Efficiency of Alternate Algorithms

Enhancing hill climbing with additional features improves effectiveness but increases complexity. Variants like Steepest-Ascent, First-Choice, and Random Restart enhance heuristics but have drawbacks. Choosing the right version depends on the specific puzzle and associated costs.

# Conclusions and Lessons Learned

03

Annealing  
Expectancy

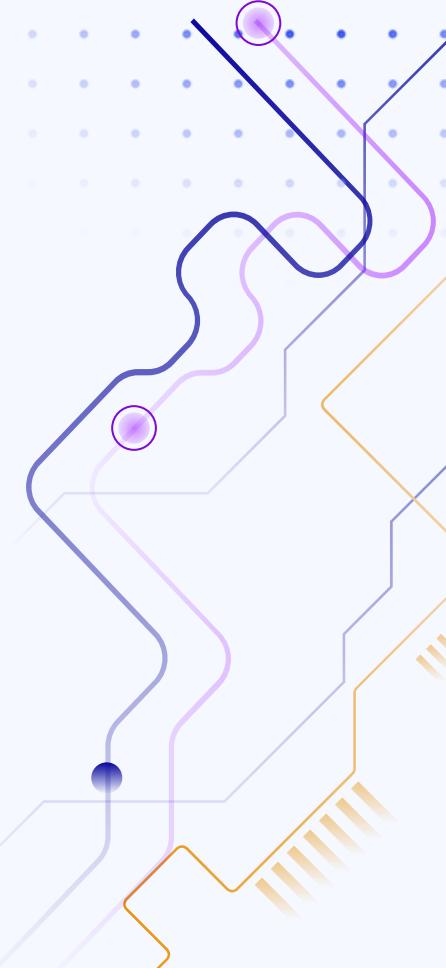
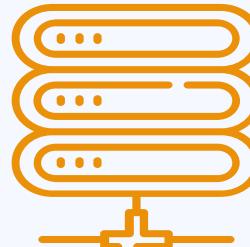
Simulated Annealing described a promising optimization technique because it escapes local optima by allowing occasional downhill moves. It is effective at solving complex problems, but inefficient for the puzzles studied for this assignment. The state space was discrete and small, which made it difficult for the algorithm to explore effectively, as most changes failed to improve the current state, and resulted in minimal or no progress.

# 07

# Credits and

# References.

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# References

- [1] Aimacode, "aima-python," *github.com*, Feb. 1, 2016. [Online]. Available: <https://github.com/aimacode/aima-python> . [Accessed Mar. 20, 2025].
- [2] U. Rawat, "Hill Climbing in Artificial Intelligence," *geeksforgeeks.org*, Oct. 10, 2024. [Online]. Available: <https://www.geeksforgeeks.org/introduction-hill-climbing-artificial-intelligence/>. [Accessed: Mar. 25, 2025].
- [3] Cyfuture Cloud, "Introduction to Hill Climbing in Artificial Intelligence," *cyfuture.cloud*, [Online]. Available: <https://cyfuture.cloud/kb/general/introduction-to-hill-climbing-in-artificial-intelligence>. [Accessed: Mar. 25, 2025].
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