Adaptive Navigation Strategies: Evolving Algorithms for Efficient Real-World Pathfinding in Dynamic Environments

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Artificial Intelligence Coursework

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This report assesses diverse AI methodologies for solving complex problems and explores supplementary strategies to enhance decision-making and optimisation in real-world scenarios. It investigates these approaches' impact on adaptive navigation and efficient pathfinding, offering critical insights into their strengths and potential improvements for dynamic problem-solving.

Part 1

The A* search algorithm is implemented to find an optimal path, minimising the agent's moves from its current position to a specified destination (either in type or location). It's tailored to handle scenarios where the agent may lack sufficient energy to reach the intended endpoint. In such instances, the algorithm checks if the destination can be reached by visiting the closest charging stations along the way. This adaptive approach ensures effective navigation, considering both energy constraints and access to charging stations throughout the agent's route.

Although the A* search algorithm may consume more memory compared to the initial Breadth-First Search (BFS) implementation, especially when dealing with large grids, the heuristic-driven strategy provides more efficient pathfinding compared to the BFS search algorithm for location-specified tasks.

Considering Genetic Algorithms (GAs) excel in optimising solutions in complex and dynamic environments, integrating GA into A* could significantly improve the algorithm's capabilities. Enhancing the A* search with GA can evolve and fine-tune the heuristic function based on various factors such as energy consumption, distance to charging stations, and potential obstacles. This adaptation will enable the agent to plan paths more effectively using the algorithm.

For instance, if the algorithm is used for medical robot navigation within a hospital, the robot will efficiently plan routes utilising an improved version of the A* search with GA. The algorithm will consider real-time data inputs, influencing adaptive route planning. The heuristic function in path selection processes will evolve considering factors like traffic patterns, possible obstacles, urgency, and other dynamic environmental factors in the hospital environment.

Part 2

The initial approach involved checking the closest oracle using BFS search and going to a charging station when the energy level dropped below a certain threshold. However, this method had issues, such as the absence of a heuristic function and an inefficient way to manage energy.

The improved method marks a significant change by avoiding unnecessary charging when the agent could visit more oracles before recharging and by reducing unnecessary movements when there were no more oracles to visit. It starts by checking all oracles and charging stations right from the beginning. This approach provides efficient pathfinding, reducing unnecessary searching and enabling A* search. In this implementation, the algorithm checks if the agent can reach the nearest charging station after visiting the nearest oracle. Movement only happens if there are other accessible oracles to visit, optimising the agent's path.

Integrating the concept of Emergence and Norms Conflict into this algorithm could greatly enhance its real-world capabilities. While various AI approaches will possibly offer benefits as well, the unique advantage lies in a system's ability to adapt and self-regulate through emergent behaviours and conflicting norms. The original algorithm may struggle when faced with unexpected changes, lacking flexibility. By allowing emergent behaviour and adaptive norms, the algorithm can dynamically adapt to unforeseen circumstances or environmental shifts. For instance, encountering unexpected obstacles or changes in charging station availability can prompt the system to adjust its norms without explicit reprogramming. As this adaptability ensures more robust decision-making, particularly in dynamic environments where predefined rules might falter, it offers greater potential for better resilience and effectiveness in navigating complex real-world challenges.

Part 3

The maze-solving algorithm is designed to navigate through a maze using one or multiple agents. Each agent progresses along the path, adding divergence points to a queue for exploration later. When an agent reaches a standstill or a dead-end, it moves to an unexplored divergence in the queue and continues exploring from there.

When using a single agent, the algorithm functions similarly to Depth-First Search (DFS). However, employing a multi-agent system approach, when agents potentially collide, they check each other's direction upon meeting and resolve the situation. If there's a potential collision, the agents coordinate to prevent blockage by either waiting or adjusting their route to avoid deadlocks. In case they are moving in opposite directions, they exchange their routes. When an agent discovers the maze's exit, it signals the other agents to cease their exploration, enabling them to swiftly navigate to the exit without further exploration.

When considering solving real-world maze-like problems, employing Brooks and Nouvelle AI principles could significantly enhance performance. The essence of this approach lies in the philosophy of embodied intelligence, emphasising agents' direct interaction with the maze environment. This principle would empower the agents to integrate sensorimotor feedback, adapting their strategies based on immediate environmental cues. Moreover, decentralised control mechanisms align with the algorithm, enabling agents to autonomously coordinate using local information, leading to more efficient navigation strategies, especially in complex maze environments. Additionally, this approach fosters robustness in dealing with uncertainties and dynamic changes, crucial for the maze-solving algorithm to navigate unpredictable or dynamically altering maze structures. Compared to other AI approaches, such as evolutionary algorithms or MAS simulation, the direct connection and embodied interaction with the environment proposed by Brooks' principle are considered to potentially equip agents better to understand and navigate the maze in complex real-world scenarios.

Conclusion

In conclusion, this report assessed diverse AI methodologies for real-world pathfinding. The A* algorithm optimised navigation considering energy constraints, while integrating Genetic Algorithms showed promise for dynamic improvements. Enhanced route-planning strategies prioritised heuristic functions and adaptability, vital for unforeseen scenarios. Multi-agent maze-solving, guided by embodied intelligence principles, highlighted efficient navigation in complex environments. These findings demonstrate the potential of AI strategies to revolutionise pathfinding, emphasising adaptability and efficiency in addressing real-world challenges.