

“Path Planning for Autonomous Robots using Quantum Reinforcement Learning”

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ABSTRACT-This research work focuses on the application of Quantum Reinforcement Learning (QRL) to improve path planning for autonomous robots. Traditional path planning techniques are prone to failure in handling the complexity of uncertain and dynamic environments, but QRL leverages the power of quantum computing to exploit the principles of superposition and parallelism to improve decision-making and optimization processes. By integrating QRL with existing reinforcement learning techniques, the proposed technique quickens the pace of learning processes and improves the quality of path planning to enable robots to navigate around obstacles more effectively with shorter travel time and lower energy costs. Simulation results show that QRL outperforms traditional techniques in convergence speed and optimality of path solutions and offers a promising solution for practical autonomous navigation.

Keywords: Dynamic Environment, Path Planning, Autonomous Navigation, Obstacles avoidance.

I. INTRODUCTION

Autonomous robot navigation is highly dependent on effective path planning. Conventional path planning algorithms and traditional reinforcement learning algorithms may encounter difficulties in terms of slow convergence speed and high computational complexity, particularly when the state and action spaces are large. Recent breakthroughs in quantum computing bring new hopes to this area, and the principles of superposition and parallelism are promising. This paper investigates the use of Quantum Reinforcement Learning (QRL) to improve robot path planning by achieving faster learning, better decision-making, and more optimal and energy-efficient paths. Simulation experiments show that QRL performs better than traditional methods in terms of convergence speed and optimality of paths.

II LITERATURE REVIEW

2.1 Cristiano Souza De Oliveria(2025): Trajectory Planning for Autonomous Cars in Low-Structured and Unstructured Environments

The architecture consists of three components: a Table On boarder for pre-processing the schema, a hybrid LLM-based SQL Generator, and a Feedback Augmentation loop. The SQL Generator attempts to find matches in a set of verified examples before employing a multi-agent pipeline (Planner, Generator, Critic) for new queries. The design is intended for high reliability in real-world scenarios.

2.2 Ibrahim(2025):Autonomous Mobile Robot Path Planning Techniques—A Review: Classical and Heuristic Techniques

The proposed approach combines traditional path planning algorithms (like A* and Dijkstra's algorithm) with heuristic algorithms (like Genetic Algorithms and Simulated Annealing) to improve the efficiency and flexibility of path planning. The proposed approach aims to reduce the computational time as much as possible while keeping robustness in the unknown and dynamic environment. By using both approaches, it tries to find global optimal solutions with local adaptation. The proposed hybrid approach is intended to handle complex and unexpected situations with better real-time performance.

2.3 YMUHAMMAD AIZAT (2023): A Survey on Navigation Approaches for Automated Guided Vehicle Robots in Dynamic Surrounding

The proposed approach combines real-time dynamic path planning and sensor fusion for enabling safe and adaptive navigation of AGVs in dynamic environments. The approach combines model predictive control (MPC) and

reinforcement learning (RL) for adapting trajectories based on environmental feedback. The approach combines real-time path planning and sensor fusion to enable AGVs to adapt to dynamic environments in real-time.

2.4 Soohyun Park (2024): Quantum Multi-Agent Reinforcement Learning for Autonomous Mobility Cooperation

The proposed method utilizes Quantum Multi-Agent Reinforcement Learning (Q-MARL) to achieve better coordination among autonomous agents in dynamic environments. The application of quantum computing enables it to accelerate decision-making processes and improve the efficiency of communication between the agents. The method aims to achieve quicker convergence to optimal strategies, hence promoting more efficient cooperation between autonomous agents in mobility-related tasks. The combination of quantum computing and multi-agent reinforcement learning (MARL) greatly improves the cooperation and coordination of autonomous agents in dynamic environment.

2.5 S. Samsudeen (2025): Q-SHIELD: A Quantum Safety-Aware Heuristic for Intelligent Evasive Lane Decision-Making in Autonomous Vehicles

Safety In the fast developing area of autonomous vehicles, it is essential to think about the safety aspect as one of the most important tasks. There is a requirement for fast and accurate decision-making even in uncertain driving conditions. The autonomous vehicles fully depend on the real-time sensor data. Therefore, fast decision-making is actually a tough task in the autonomous vehicle. The processing of massive voluminous data is still a tough task for the conventional computing models, whereas speed and accuracy are taken as the most important task in fast decision-making. Q-Shield safety-aware quantum model is proposed to carry out the intelligent Evasive Lane detection in order to make fast decisions while driving.

2.6 Jian Wang (2026): Motion-Constrained Path Planning and Following for a Biomimetic Underwater Exploration Robot

Biomimetic underwater platforms are essential instruments for water quality monitoring and environmental sensing tasks, in which optimal trajectory planning and energy control have a direct effect on the quality of measurement coverage and data acquisition. This paper focuses on the challenges of trajectory planning for underwater exploration platforms in sensing missions, and a new method is presented to improve the efficiency of measurements and prolong the measurement mission duration. First, a path planning strategy based on motion constraints is established, in which the global path is planned with the initial directional choice by the A* algorithm and the local obstacle avoidance by the iterative linear quadratic regulator with piecewise sampling smoothing. Furthermore, an offline optimization strategy is formulated to optimize the stiffness coefficients of the flexible tail to decrease energy consumption and prolong the measurement mission duration.

2.7 Muhammad Aizat (2024): Comprehensive Review of Recent Advances in Automated Guided Vehicle Technologies

Automated guided vehicles (AGVs) have recently gained much attention in the field of academic research and industry applications because of several benefits, such as enhanced mobility and safety. AGVs are designed to move along a predetermined path; however, in case the path is blocked, how will the AGV avoid or move through the path by choosing the new path with the safest actions? This paper found several advanced methods that have been widely used in the operation of AGVs in order to avoid dynamic obstacles and be able to work in a complex environment.

2.8 Chizhou Zhang (2025): LiDAR-Based Autonomous Exploration Method of Mobile Robot Using Deep Reinforcement Learning in Unknown Environments

The autonomous exploration has a great application value in tasks such as mine exploration and environmental modeling, and personnel search and rescue, which can effectively improve the efficiency of the task. Learning-based approaches are very suitable for these tasks. However, they have the problems of low learning efficiency and difficulty in simulation-to-reality transfer. In order to improve the efficiency of the exploration process of the mobile robot, a new 3-D LiDAR-based autonomous exploration approach based on deep reinforcement learning in unknown environments is proposed. In particular, a sparse informative graph based on the complementary holes is proposed, which is the input of our model.

2.11. Comparison Table: Literature Review on Path Planning and Obstacles Avoidance.

Author(s)	Titles	Methodology	Contribution	Limitation
Cristiano Souza De Oliveria(2025):	Trajectory Planning for Autonomous Cars in Low-Structured and Unstructured Environments	The proposed methodology combines multi-sensor information to create a real-time environmental model and a traversability map for safe passage in low-structured and unstructured environments. Trajectory candidates are computed and optimized based on vehicle kinematic constraints and cost functions for safety, comfort, and optimality, with real-time replanning to address dynamic obstacles and environmental changes.	In this paper, a robust and adaptive trajectory planning approach for autonomous vehicles in low-structured and unstructured environments is proposed. The approach combines real-time perception, traversability analysis, constrained trajectory optimization, and dynamic replanning.	The proposed method is constrained by high computational complexity, dependence on accurate sensor information, and a need for extensive validation in highly dynamic and uncertain environments.
Ibrahim(2025):	Autonomous Mobile Robot Path Planning Techniques—A Review: Classical and Heuristic Techniques .	This research examines and classifies existing classical (such as graph-based and mathematical models) and heuristic (such as evolutionary and biologically inspired algorithms) approaches to path planning in autonomous mobile robots, based on	This review offers a thorough comparative examination of classical and heuristic approaches to path planning in autonomous mobile robots, discussing their merits and demerits, performance criteria, and applicability to	This review is subject to limitations imposed by existing literature on the topic, possible differences in experimental settings among the works being compared, and the lack of a common benchmark for direct comparison of performance.

		parameters such as optimality, complexity, scalability, and dynamic environment adaptability.	various static and dynamic environments.	
YMUHAMMAD AIZAT (2023):	A Survey on Navigation Approaches for Automated Guided Vehicle Robots in Dynamic Surrounding	The contribution of this survey is to compile and discuss different navigation strategies for AGVs in dynamic environments.	The methodology of this survey is to review and classify the existing navigation strategies for AGVs, and then compare them on the basis of adaptability, real-time performance, collision avoidance, and appropriateness for dynamic and uncertain environments.	The limitations of this survey are that it relies on the existing literature, and the experimental conditions are not standardized across different studies. There are no standardized benchmarks to compare the performance of different navigation strategies in dynamic environments..
Soohyun Park (2024)	Quantum Multi-Agent Reinforcement Learning for Autonomous Mobility Cooperation	Integrates the concepts of quantum computing, including superposition and entanglement, with multi-agent reinforcement learning to efficiently explore the state-action space in parallel and optimize cooperative behavior for autonomous agents.	Proposes a Quantum Multi-Agent Reinforcement Learning (QMARL) approach that enhances cooperation, decision-making, and learning speed among autonomous agents in a complex setting.	Restricted by the current limitations of quantum hardware, computational complexity, scalability issues for large autonomous agent systems, and a lack of practical validation.
S. Samsudeen (2025)	Q-SHIELD: A Quantum Safety-Aware	Combines quantum computing	Proposes **Q-SHIELD**, a quantum-based	The proposed method is limited by the current

	Heuristic for Intelligent Evasive Lane Decision-Making in Autonomous Vehicle	methods with heuristic decision-making to analyze multiple lane change alternatives, estimate safety risks in real-time, and determine optimal evasive actions in dynamic traffic environments.	safety-aware heuristic that enables autonomous vehicles to make intelligent evasive lane decisions, improving collision avoidance and overall driving safety in complex traffic scenarios.	state of quantum hardware, real-time computational complexity, and a lack of real-world validation in traffic environments.
Jian Wang (2026)	Motion-Constrained Path Planning and Following for a Biomimetic Underwater Exploration Robot	The methodology of this work involves the use of kinematics and dynamics of the biomimetic robot, as well as motion-constrained path planning and tracking techniques.	The contribution of this work is to propose a motion-constrained path planning and tracking approach for biomimetic underwater exploration robots.	The limitation of this work is that it is affected by uncertainties in the environment, complexity of the computation for real-time processing, and the need for field testing.
Muhammad Aizat (2024)	Comprehensive Review of Recent Advances in Automated Guided Vehicle Technologies	The methodology of this review is to systematically survey and classify state-of-the-art AGV technologies from the literature, and compare different technologies based on performance, innovation, application, and adaptability.	The contribution of this review is to provide a comprehensive overview of recent developments in Automated Guided Vehicle (AGV) technologies, including recent developments in navigation, control, sensing, communication, and applications, in order to guide future research	The limitation of this review is that it is based on existing literature, and there may be variability in the experimental conditions in different studies, and there may not be a standard benchmark for comparison.

			and development.	
Chizhou Zhang (2025)	LiDAR-Based Autonomous Exploration Method of Mobile Robot Using Deep Reinforcement Learning in Unknown Environments	Combines LiDAR sensor information with a deep reinforcement learning framework to enable the mobile robot to sense its environment, navigate in real-time, and explore unknown environments through trial-and-error learning.	Contributes a LiDAR-based deep reinforcement learning framework for autonomous mobile robots that facilitates efficient exploration and navigation of unknown environments while avoiding obstacles and maximizing path coverage.	The proposed approach has limitations in terms of high computational complexity, the need for accurate LiDAR sensing, possible difficulties in highly dynamic or cluttered environments, and the requirement for a considerable amount of training before actual deployment.

3. Research Gaps:

i.Limited Applicability of QRL in Complex Scenarios:

The Most of the current literature on reinforcement learning for robot navigation considers static or semi-static scenarios. The applicability of Quantum Reinforcement Learning to dynamic and uncertain scenarios remains largely unexplored.

ii.Scalability Issues:

Conventional RL faces difficulties in dealing with large state and action spaces, resulting in slow convergence and high computational complexity.

Although QRL offers parallelism, its applicability to large-scale autonomous systems remains limited.

Research is required on scalable QRL algorithms that can be applied to real-world autonomous robots.

iii.Integration with Conventional RL:

Few studies have shown the capability of QRL to improve the existing architectures of RL without the need for a fully quantum machine. Reinforcement learning to achieve a balance between the quantum speedup and the feasibility of implementation.

iv.Energy and Resource Optimization:

Although QRL is expected to decrease the travel time, few studies have been conducted to quantify the energy efficiency and resource utilization in robot path navigation tasks.

A comprehensive analysis of the capability of QRL to reduce energy consumption and optimize path planning is absent.

4. CONCLUSION

This project “Path Planning for Autonomous Robots using Quantum Reinforcement Learning” Successfully demonstrates an intelligent and interactive approach to robot path planning in a grid-based environment. By combining

quantum-inspired probabilistic exploration with traditional path planning, the system is able to efficiently calculate feasible paths while avoiding obstacles.

5. REFERENCES

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