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Deep Reinforcement Learning-Based Path Planning with Dynamic Collision Probability for Mobile Robots

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Abstract— **This study proposed a novel approach for mobile robots path planning and avoiding collisions by using Collision Probability (CP) along with the Soft Actor-Critic Lagrangian (SACL-L) framework. Our approach enables the mobile robot to dynamically deal with static and dynamic environments while ensuring safety and efficiency. The proposed SAC-L (CP) aims to minimize the total costs, which is the combination of both negative rewards and collision occurs. This dual focus strategy ensures trajectory planning inherently safer and providing a robust solution for complex dynamic obstacles environments. The framework's efficiency is validated through extensive simulations on the Gazebo platform involving three increasingly difficult scenarios, demonstrating superior performance, adaptability and safety of our approach compared to traditional Deep Reinforcement Learning (DRL) methods. Our results showcase significant improvements in social and ego safety scores, contributing to the advancement of autonomous navigation in complex environments. This framework marks a step towards safer, more reliable mobile robot navigation and opens new avenues for future research in mobile robot path planning. A supplementary video further demonstrates the effectiveness of our framework.[1].**

I. INTRODUCTION

In recent years, mobile robotics has experienced significant advancements, propelling the capabilities of robots in navigating complex and dynamic environments[11]. The integration of mobile robots into various sectors, including logistics, healthcare, and service industries, underscores the growing importance of developing robust, efficient, and safe navigation systems; the demand for sophisticated navigation capabilities that ensure both efficiency and safety in dynamic environments has never been greater [4][13]. The integration of mobile robots not only promises to enhance operational productivity but also to open new avenues for service delivery and support.

Ensuring reliable collision-free navigation remains a cornerstone challenge in the broader adoption of mobile robotics. This challenge is magnified by real-world environments' inherent unpredictability and complexity, where static and dynamic obstacles necessitate advanced perceptual and decision-making capabilities [1][9]. Traditional path-planning approaches have made significant strides; however, they often fall short in dynamically evolving scenarios, highlighting the need for adaptive and anticipatory strategies [3][16].

Existing policies can provide robust path planning in controlled environments but they often lack in performance where flexibility and adaptability are essential in dynamic environments. Our main contribution introducing a novel approach to safer autonomous navigation that combines the Soft Actor-Critic Lagrangian framework with existing collision probability estimates [1]. This integration of collision probability into its cost function enabled this approach to dynamically adjust the Lagrange multiplier for collision risk management. Using collision probability in the cost function allows the mobile robot more proactive and sophisticated in path planning, ensuring that the learning process and the navigation strategies are more optimized without compromising efficiency. The potential negative impact of collisions is now explicitly considered via the cost function, which uses a scaling factor to modify how much the probability of a collision influences decision-making. For mobile robot path planning robust and efficient solution is achieved with the use of computational resources and accurate collision probability calculations. We enhance robot decision-making ability when collisions are most likely to occur. This is a key component that increases understanding of environmental risks and is important to improve learning for mobile robots while navigating through complex environments.

Furthermore, we comprehensively tested our approach across different situational environments that were specifically created to replicate real-world navigation challenges. The experimental results show substantial improvements in safety measures and navigation effectiveness, highlighting the success of our approach.

II. RELATED WORK

Path planning in mobile robotics has evolved over the years, from traditional path planning algorithms, machine learning algorithms (Ant Colony Optimization, Genetic Algorithm), and heuristic search algorithms (A*, D*, RRT*) [15] to advanced DRL approaches. Classical approaches have been highly reliable in offering optimal or near-optimal solutions for navigating through static environments with predefined obstacles. However, these approaches have limitations when they are applied to dynamic environments where the surroundings change unpredictably, requiring real-time decision-making and adaptation. The advent of DRL approaches, such as Proximal Policy Optimization (PPO), Deep Deterministic Policy Gradient (DDPG), and Twin-Delayed

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[1]https://youtube.com/shorts/O-X-IgtlMAI?feature=share