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# Enhancing GRU-Based DRL with Delta-LiDAR for Robust UAV Navigation in Partially Observable Dynamic Environments

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**ABSTRACT**

Partial observability and sensor limitations are challenging for the navigation of autonomous Unmanned Aerial Vehicles (UAVs). Deep Reinforcement Learning (DRL) algorithms have emerged as potential tools in advancing this field. However, their effectiveness degrades in challenging environments, particularly in the presence of dynamic obstacles. Recent research trends emphasize the need for new DRL variants that guarantee robustness, real-time adaptability, and improved generalization under uncertainty. This paper proposes a lightweight DRL architecture that combines Proximal Policy Optimization (PPO) with a Gated Recurrent Unit (GRU), extended with a temporal LiDAR differencing feature called Delta-LiDAR. The difference between consecutive LiDAR scans is computed to provide the velocity and directional cues without the computational burden of Long Short-Term Memory (LSTM) networks. We evaluate three models, PPO-LSTM, PPO-GRU, and Delta-LiDAR augmented PPO-GRU in a 3D simulated UAV navigation environment characterized by noise, clutter, and dynamic obstacles. We considered several metrics, including success rate, collision frequency, trajectory smoothness, and computational efficiency, to determine the effectiveness of each architecture. The experimental results demonstrate that Delta-LiDAR improves GRU-based temporal reasoning. The deployment complexity is reduced compared with the LSTM-based architecture, which makes it ideal for real-time UAV operation in partially observable environments.

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## 1. INTRODUCTION

Unmanned aerial vehicles (UAVs) have become indispensable tools in numerous applications, such as surveillance [1], environmental monitoring, flood detection, and disaster relief. In these domains, autonomous flight in an unstructured and dynamic environment is critical [2-4]. However, robust and adaptable navigation in such scenarios remains challenging, particularly under conditions of partial observability [5], sensor noise, and environmental uncertainty [6]. Classic RL algorithms work well in stable and clear environments, but they often struggle and fail in situations with moving obstacles or fluctuating sensor input [7-9].

Early attempts to apply RL algorithms to UAV navigation were value-based methods, such as Deep Q-Networks (DQN) [10]. In this approach, the decision-making process is done by choosing the action with the highest value. While this method is effective in a discrete action space (e.g., simple grid-world navigation), it struggles in a continuous action space required in UAV applications [11]. Policy-based approaches can handle this by directly optimizing the policy using gradient ascent without requiring a value function. In high-