Recent Advances in Reinforcement Learning-Based Autonomous Driving Behavior Planning: A Survey

Jingda Wu, Chao Huang, Hailong Huang, Chen Lv, Yuntong Wang, and Fei-Yue Wang

Abstract—Autonomous driving (AD) holds the potential to revolutionize transportation efficiency, but its success hinges on robust behavior planning (BP) mechanisms. Reinforcement learning (RL) emerges as a pivotal tool in crafting these BP strategies. This paper offers a comprehensive review of RL-based BP strategies, spotlighting advancements from 2021 to 2023. We completely organize and distill the relevant literature, emphasizing paradigm shifts in RL-based BP. Introducing a novel categorization, we trace the trajectory of efforts aimed at surmounting practical challenges encountered by autonomous vehicles through innovative RL techniques. To guide readers, we furnish a quantitative analysis that maps the volume and diversity of recent RL configurations, elucidating prevailing trends. Additionally, we delve into the imminent challenges and potential directions for the future of RL-driven BP in AD. These directions encompass addressing safety vulnerabilities, fostering continual learning capabilities, enhancing data efficiency, championing collaborative vehicular cloud networks, integrating large language models, and enhancing ethical considerations.

Index Terms—Autonomous driving, reinforcement learning, behavior planning, decision, autonomous vehicle.

I. INTRODUCTION

AUTONOMOUS driving (AD) has the potential to enhance transportation efficiency and boost societal well-being [1]–[3]. Over the past few years, this subject has attracted significant scholarly attention [4]. Currently, two main architectural approaches dominate AD systems: the pipeline style and the end-to-end style [5]. In both architectures, the behavior planning (BP) module plays a crucial role in dictating autonomous vehicle (AV) actions and has become a central point of academic exploration [6]–[8]. The rise of data-driven approaches and the rapid evolution of machine intelligence have positioned reinforcement learning (RL) algorithms [9], renowned for their robust representational abilities [10] and optimization effectiveness [11], at the forefront of strategies for autonomous driving behavior planning (ADBP) [12].

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The acronyms used in this paper can be found in the appendix A1.
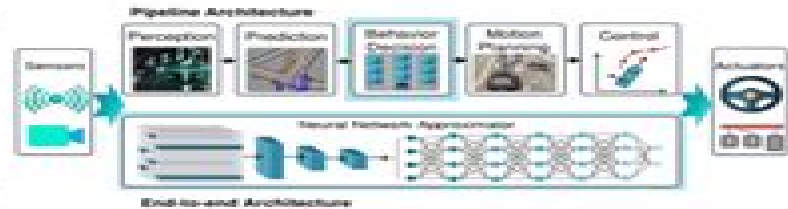
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Fig. 1. Schematic representation of two AD architectures. The top branch depicts the pipeline-style architecture, comprised of sequential functions with an explicit BP function named behavior decision (highlighted). The bottom branch illustrates the end-to-end neural network-based architecture that seamlessly integrates all functions, implicitly encompassing the BP function.

Initial studies in this domain focused on directly utilizing classical RL algorithms to craft a functional decision agent for real-time vehicle behavior generation using environmental perception data. This focus led to an extensive body of related literature [13]–[16]. For a thorough understanding of these early endeavors (up to 2021), we recommend several comprehensive reviews [17]–[24]. However, as the research has advanced, certain limitations of classical RL techniques, including safety, data efficiency, and generalization challenges, have surfaced. As a result, RL-based BP research has predominantly remained within academic confines, with limited appeal for commercial applications. In the recent three years, there has been an upswing in ADBP studies targeting these limitations through innovative RL theories. Yet, there is a dearth of reviews that holistically encapsulate these contemporary investigations.

This gap motivates us to provide a comprehensive overview of RL-based BP strategies from the last three years (2021–2023) and outline future directions. Our contributions include:

- A synthesis of the latest literature on RL-based BP strategies, spotlighting the innovative shifts in recent years.
- A novel categorization perspective that is uniquely anchored on addressing practical challenges faced by RL-based AVs using cutting-edge RL theories.
- A quantitative assessment for recent studies based on their diverse RL configurations.
- Insights of challenges and promising avenues in RL-based BP.

The subsequent sections are organized as follows: Section 2 introduces the fundamental concepts and prevailing classifications of ADBP strategies. Section 3 covers the basics of RL and highlights various new approaches used to address the deficiencies in the classical RL theory. Section 4 presents

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