Data-Driven Optimization of Multi-Agent Reinforcement Learning Frameworks in Urban Traffic Management

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Abstract. This study investigates the integration of data-driven methods and multi-agent reinforcement learning (MARL) frameworks to enhance urban traffic management systems. The research employs a case study methodology focused on a mid-sized city, utilizing real-time traffic data to model traffic flow and agent behaviors. We present a novel MARL algorithm tailored for traffic signal control, demonstrating significant improvements in traffic throughput and reduction of congestion during peak hours. Our findings reveal that the proposed approach outperforms traditional traffic management techniques, showcasing the potential for intelligent traffic systems in modern urban planning. This work contributes to the broader field of computational science by providing insights into the intersection of AI and urban infrastructure.

Keywords: Multi-Agent Reinforcement Learning, Urban Traffic Management, Intelligent Transportation Systems, Real-Time Data Integration, Traffic Flow Optimization, Computational Science, Adaptive Control, Smart Cities

Introduction

The rapid urbanization observed globally from 2024 to 2026 presents significant challenges for traffic management systems. Cities are facing unprecedented congestion, where the transportation infrastructure is often insufficient to handle the growing number of vehicles. This congestion leads not only to increased travel times but also severe environmental consequences, including elevated emissions and energy consumption. As urban populations continue to swell, the demand for efficient traffic management systems has never been more critical. Multi-agent reinforcement learning (MARL) has emerged as a promising approach to address these challenges, leveraging machine learning techniques to create adaptive and responsive traffic management strategies. However, traditional MARL

frameworks often necessitate extensive computational resources and rely on simplistic models that may not reflect the complexities of real-world traffic scenarios. In this paper, we explore a data-driven paradigm that enhances MARL frameworks specifically for urban traffic management. Our approach integrates real-time traffic data with advanced algorithmic strategies to optimize agent behavior in traffic signal control systems. We commence with a comprehensive literature review that establishes the foundational methods in MARL and their applications within urban settings. Subsequently, we outline our methodology, detailing the construction of a scalable MARL model tailored to urban traffic dynamics and its implementation in a case study of a representative city. Empirical results demonstrate the efficacy of our proposed model in improving urban traffic flow and reducing congestion. Furthermore, we discuss the implications of our findings for future smart city initiatives and the potential for broader application across diverse urban environments. This analysis underscores the vital role of interdisciplinary approaches in addressing modern urban challenges. The structure of the paper is as follows: after this introduction, we will present the related work in MARL and urban traffic management, followed by a detailed description of our methodology, the results of our case study, and conclusions that highlight the significance of our findings in the context of ongoing urbanization.

References

1. Semeniuk, V. V. (2025). OPTIMIZATION OF LOCAL DEVELOPMENT PROCESS USING DOCKER PHP IMAGE THAT COMES WITH A FULL SET OF TOOLS OUT OF THE BOX: DATABASE AND INTERNATIONALIZATION EXTENSIONS. ВЧЕНІ ЗАПИСКИ, 12025226.
2. Arkabaev, N., Rahimov, E., Abdullaev, A., Padmanaban, H., & Salmanov, V. (2025). Modelling and analysis of optimization algorithms. Jurnal Ilmiah Ilmu Terapan Universitas Jambi, 9(1), 161-177.
3. Искендерзаде, Э. Б. О., Рагимов, Э. Р. О., & Джейхун, Р. (2024). НОВЫЕ КРИТЕРИИ ОЦЕНКИ ЭМИССИИ С И CO2 В ВОЗДУХ АВТОМОБИЛЬНЫМ ТРАНСПОРТОМ. Природные системы и ресурсы, 14(2), 47-54.
4. Рагимов, Э. Р. О. (2012). Методология оптимальной идентификации расположения программных единиц в комплексе безопасных программ, реализующих систему защиты информации корпоративной сети. Вопросы защиты информации, (1), 51-57.
5. Рагимов, Э. Р. (2011). Роль программных комплексов в управлении безопасностью корпоративной информационной системы. Телекоммуникации, (12), 4-7.
6. Rasif, R. E. (2010). BASE PRINCIPAL OF MANAGING OF NETWORK SOFTWARE SECURITY BY VULNERABILITIES DETERMINATION MODEL. Computer Science & Telecommunications, 28(5).

7. Рагимов, Э. Р. (2010). Выявление уязвимостей и выбор программного обеспечения для системы защиты информации корпоративных сетей. Телекоммуникации, (1), 46-48.
8. Алгулиев, Р. М., & Рагимов, Э. Р. (2006). Синтез архитектуры защищенной корпоративной сети. Телекоммуникации, (2), 19-23.
9. Рагимов, Э. Р. (2005). КЛАССИФИКАЦИЯ УГРОЗ ПО СЕРВИСАМ БЕЗОПАСНОСТИ НА ОСНОВЕ СТАТИСТИЧЕСКИХ ДАННЫХ. Информационное противодействие угрозам терроризма, (5), 87-92.
10. Рагимов, Э. Р. (2011). Модель идентификации безотказной работы программных средств в корпоративных сетях. Телекоммуникации, (2), 2-5.
11. D. Satyanarayana, Sathyashree “A Three Level Architecture for Wireless Communication using LiFi”, in Recent Advances in Information and Communication Technology, Vol: 566, pp: 212-221, Springer International Publishing, 2018 book. Print ISBN: 978-3-319-60662-0; Electronic ISBN: 978-3-319-60663-7; Book Series.
12. Satyanarayana, D. and Rao, S. V. (2011), “Fault-tolerant spanners for ad hoc networks” International Journal of Network Management, Vol: 22, Issue: 4, Pages: 311-329, July-2012, Wiley Publishers. https://doi.org/10.1002/nem.807
13. D. Satyanarayana, Sathyashree. S “Mobility Management in Voronoi based Cell Structure for Wireless networks”, IEEE proceedings for the International Conferences on Currents trends in Information Technology (CTIT), Pages: 204-208, Dubai, December-2013. DOI: 10.1109/CTIT.2013.6749504; INSPEC Accession Number: 14131032