

Chapter 9

Graph-Based Machine Learning for Enhanced Traffic Management: Optimizing Efficiency and Mobility

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ABSTRACT

The urban population's rapid growth has heightened traffic congestion challenges, necessitating innovative solutions. This paper explores the potential of Graph-Based Machine Learning (GBML) in transforming traffic management. It focuses on enhancing efficiency to reduce travel times and congestion, and improving mobility for a better user experience and urban accessibility. We assess the effectiveness of logistic regression and random forest for classifying traffic situations. While logistic regression offers interpretability, random forest outperforms it in accuracy. Random forest excels in capturing complex traffic data relationships, aiding tasks like traffic flow prediction and anomaly detection. Its adaptability to diverse datasets ensures robust performance across various traffic scenarios. Therefore, random forest emerges as the more valuable methodology in traffic analysis due to its superior accuracy, robustness, and adaptability to complex traffic patterns.

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1. INTRODUCTION

The persistent growth of urban populations has heightened the menace of traffic congestion, giving rise to a plethora of adverse consequences with far-reaching implications. Economic losses manifest as wasted time and fuel, affecting businesses and individuals alike (Currell and Filho, 2000). Simultaneously, the surge in traffic contributes to elevated emissions, exacerbating air pollution and contributing to climate change (Newman and Kenworthy, 1989). The toll on the quality of life is profound, with congestion causing frustration, stress, and delays that impact daily commutes and overall well-being (Currell and Filho, 2000; Newman and Kenworthy, 1989; Ying et al., 2018). Traditional traffic management strategies, while essential, often fall short due to their inherent lack of adaptability and dynamism. Fixed signal timings and static route planning guidelines prove insufficient in addressing the real-time fluctuations in traffic flow, resulting in inefficiencies and mounting frustrations among commuters (Li et al., 2019; Zhang et al., 2020).

The transformative potential of GBML in revolutionizing traffic management strategies has been extensively explored in recent research. Studies have demonstrated the efficacy of graph convolutional neural networks (GCNs) in modeling spatial-temporal traffic patterns and predicting traffic flow in real-time (Ding et al., 2020; Lv et al., 2020). Additionally, the application of deep learning techniques for real-time traffic prediction and anomaly detection has been highlighted, leveraging big data to improve accuracy and efficiency (Guo et al., 2019; Li et al., 2020a; Li et al., 2020b).

Graph neural networks (GNNs) have emerged as a powerful tool for analyzing complex transportation networks. Research by Zhao et al. (2019) and Zhou et al. (2018, 2019) has shown the effectiveness of GNNs in predicting taxi demand and detecting traffic anomalies, respectively. Moreover, the integration of attention mechanisms into graph convolutional networks has been proposed by Wang et al. (2019, 2021) and Wu et al. (2020a, 2020b), enabling personalized traffic recommendations and enhancing traffic flow prediction accuracy. Despite the promising advancements in GBML for traffic management, ethical considerations must be addressed, as discussed by Xu et al. (2022). Issues such as data privacy, algorithmic bias, and societal impact need careful attention to ensure the responsible deployment of machine learning technologies in transportation systems. The comprehensive survey conducted by Xiao et al. (2021) underscores the potential of graph neural networks in revolutionizing urban traffic management. By leveraging spatial-temporal data and advanced machine learning techniques, GBML offers innovative solutions for optimizing traffic efficiency, enhancing mobility, and ultimately creating smarter and more sustainable cities.

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