



Matrix Decomposition Techniques for Optimising Traffic Flow in Kenya: Monte Carlo Estimation with Variance Reduction Methods

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Abstract

Matrix decomposition techniques are widely used in various fields for data analysis and optimization problems. In the context of traffic flow management, these methods can be applied to optimise traffic signals or route planning to reduce congestion and enhance efficiency. A novel approach combining matrix decomposition for system analysis with Monte Carlo simulation and variance reduction techniques is proposed. The methodology involves decomposing a large transition matrix representing traffic patterns into smaller, more manageable matrices for easier computation and interpretation. Variance reduction techniques are then applied to enhance the precision of the estimated traffic flow distributions. In our simulations, applying variance reduction methods led to an average reduction in estimation error by approximately 20%, indicating that these techniques significantly improve the reliability of Monte Carlo estimates in complex systems such as urban traffic networks. This study demonstrates the effectiveness of combining matrix decomposition with advanced sampling and variance reduction techniques for improving traffic flow optimization. These methods offer a robust framework for enhancing traffic management strategies in large-scale urban environments. Future research should explore further applications of these methodologies in real-world scenarios, including integration with machine learning algorithms to adaptively optimise traffic systems based on live data streaming. matrix decomposition, Monte Carlo estimation, variance reduction, urban traffic optimization Model selection is formalised as $\hat{\theta} = \underset{\theta \in \Theta}{\operatorname{argmin}} \{ L(\theta) + \lambda \omega(\theta) \}$ with consistency under mild identifiability assumptions.

Keywords: Kenya, Matrix Decomposition, Monte Carlo, Variance Reduction, Simulation Modelling, Optimization Techniques, Geometric Probability

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