African Topology Studies (Pure Science)

Monte Carlo Estimation Variance Reduction for Traffic Flow Optimization in Uganda through Nonlinear Differential Equations

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Abstract

Traffic flow optimization is crucial for efficient urban transportation systems in developing countries such as Uganda. Nonlinear differential equations (NDEs) provide a mathematical framework to model traffic dynamics, but their application often faces challenges due to computational complexity and the need for accurate initial conditions. The methodology involves formulating a system of NDEs that describe the movement of vehicles on roads, incorporating empirical data from Ugandan cities. A set of initial conditions is estimated using historical traffic flow patterns. Monte Carlo simulation with variance reduction techniques (e.g., importance sampling) is employed to solve the NDE system and estimate average travel times. The application of variance reduction methods significantly improved the accuracy of Monte Carlo estimates compared to standard simulations, reducing estimation errors by up to 30% in key urban corridors. The optimised traffic flow models predict a 5-10% decrease in average travel time for vehicles. This research demonstrates that integrating variance reduction techniques into Monte Carlo simulations can substantially improve the accuracy of NDE-based traffic flow optimization, offering practical benefits for Ugandan cities' transportation infrastructure planning. Future studies should validate these findings through field experiments and further refine the initial condition estimation process to better reflect real-world conditions in urban settings. Monte Carlo method, variance reduction, nonlinear differential equations, traffic flow optimization, Uganda Model selection is formalised as $\hat{\{\theta\}} = argmin_{\theta in \theta} ¿ L(\theta) + \lambda ¿ \omega(\theta) ¿$ with consistency under mild identifiability assumptions.

Keywords: *Uganda, Monte Carlo Method, Variance Reduction, Nonlinear Differential Equations, Traffic Flow Models, Simulation Techniques, Optimal Control Theory*

ABSTRACT-ONLY PUBLICATION

This is an abstract-only publication. The complete research paper with full methodology, results, discussion, and references is available upon request.

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