Enabling GLOSA through Domain Knowledge Aware SPAT Prediction and Queue Length Aware Trajectory Optimization

Principal Investigators:Hesham A. Rakha, Ph.D.; Amr Shafik; Seifeldeen Eteifa, Virginia Tech

SMARTER Center
A USDOT University Transportation Center

Project Overview

Researchers developed a Green Light Optimal Speed Advisory system using machine learning architectures and real-time queue estimation for traffic signal prediction. The system integrates connected vehicle data with shockwave theory to optimize vehicle trajectories at signalized intersections. This approach addresses uncertainties in actuated traffic signal timings while maximizing fuel efficiency.

Methodology

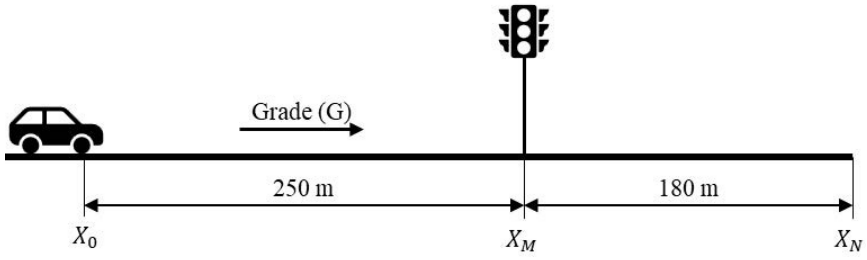
The study utilized over one year of data from six intersections along Gallows Road in Northern Virginia to train four machine learning models in an ensemble framework. Researchers combined transformer encoders with multilayer perceptrons, LSTM networks, and CNN-LSTM architectures to predict signal phase and timing information. The system incorporated real-time queue length estimation using upstream loop detector data enhanced with connected vehicle trajectories. Stochastic optimization algorithms were applied to vehicle trajectory planning, considering uncertain signal switching times and traffic conditions.

Key Findings

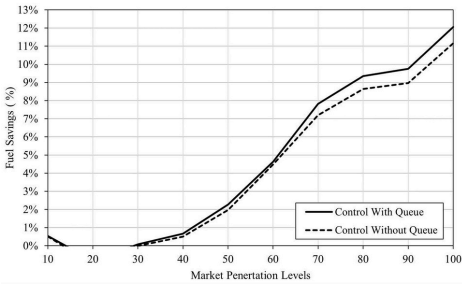
- **Prediction Accuracy:** Transformer-based architecture achieved 96% accuracy in phase change prediction with 1.49 seconds mean absolute error for exact timing predictions.
- **Consensus Performance:** Ensemble predictions with high model consensus were within one second of true values 90.2% of the time across all tested intersections.
- **Individual Vehicle Savings:** Connected vehicle-enhanced trajectory optimization delivered fuel savings of up to 35.7% for individual vehicles when incorporating queue considerations.
- **Queue Estimation Enhancement:** CV-enhanced queue estimation method outperformed standalone shockwave theory by 12.8% in improving fuel economy performance.
- **Network-wide Impact:** System achieved network-wide fuel savings of up to 12.1% at 100% market penetration levels.

Key Figures

The study models links between vehicles and traffic signals in a mixed traffic environment, with traffic signals communicating with vehicles before and after they pass through the intersection.



Test intersections in Northern VA



Fuel Savings at different Market Penetration Levels

VIRGINIA TECH

This research was led by faculty from Virginia Tech

Notes for Policymakers

Study results imply policy tools for reducing congestion through advanced signal prediction and trajectory optimization:

- **Implement connected vehicle infrastructure** for real-time data sharing and prediction accuracy.
- **Deploy machine learning systems** at intersections for reliable signal predictions.
- **Prioritize queue estimation integration** with signal controllers for improved efficiency.