Smart Arterial Management: Stable and Long-term Prediction of Intersection Queue lengths

Shakib Mustavee & Dr. Shaurya Agarwal

Civil, Environmental, and Construction Engineering Department, University of Central Florida

Introduction

Traffic congestion at the signalized intersection is one of the biggest challenges in urban traffic management. Poor traffic signal timing is one of the contributing factors to it. Optimization of signal timing can significantly reduce traffic congestion, leading to the challenge of accurately predicting traffic before starting the next cycle. Moreover, traffic flow at signalized intersections has complex nonlinear dynamics, making the optimal controller design even more challenging, as nonlinear systems are extremely difficult to control. In this poster, we present a data-driven queue length prediction framework that exploits the underlying dynamics transforming the original nonlinear dynamics into locally linear dynamics. As a case study we analyze a system of nine traffic intersections at Alafaya Trail. We accurately reconstruct (see Fig 3.) the measured north-bound queue lengths and make stable long-term predictions (see Fig.5)

Methodology

We decompose the system into two components- i) the quasiperiodic driving source with generating frequencies (see Fig 1.) and ii) the driven nonlinear dynamics. We formulate signalized intersection as a quasi-periodically driven system. Queue length of the system at any time frame $(n+1)$,

$$x_{n+1} = g_{per}(\theta_n) + g_{chaos}(\theta_n, x_n) \qquad (1)$$

where, $\theta_{n+1} = \theta_n + \Delta t\, \vec{\omega} \bmod 2\pi$ and $x_n \in R^9$ and θ_n is generating frequencies. By using Koopman operator theory and reproducing kernel Hilbert method, periodic component g_{per} is computed. It comprises of generating frequencies. Subsequently we compute the chaotic component g_{chaos}

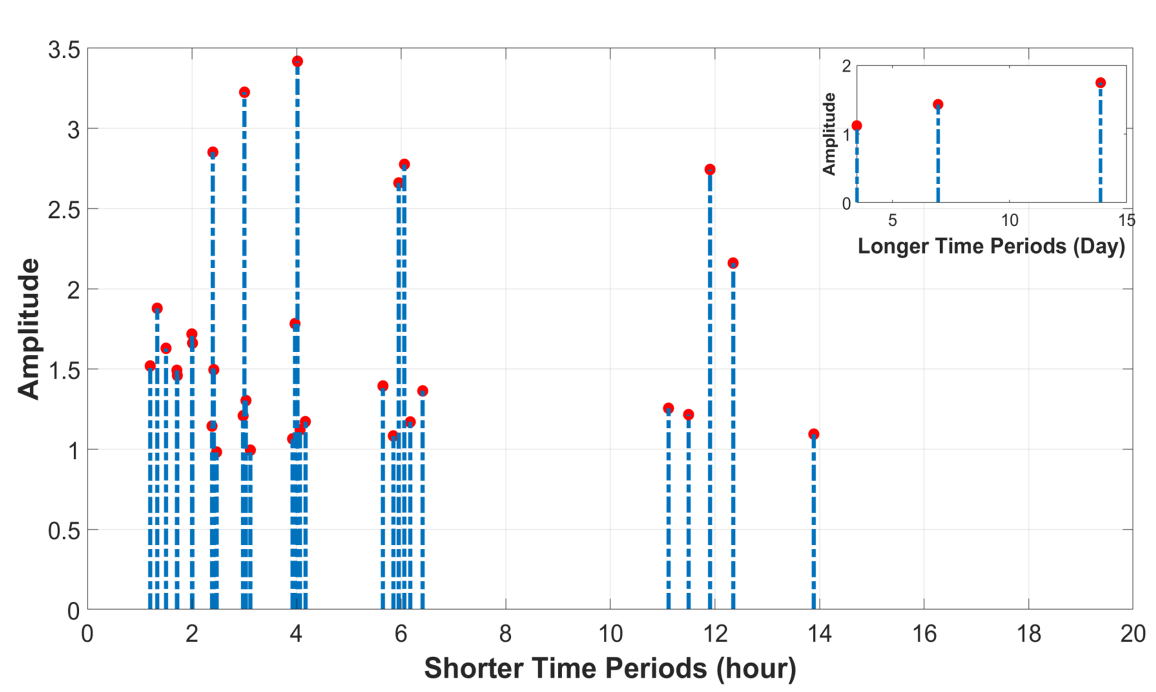

Fig 1. Generating Frequencies of Alafaya Trail

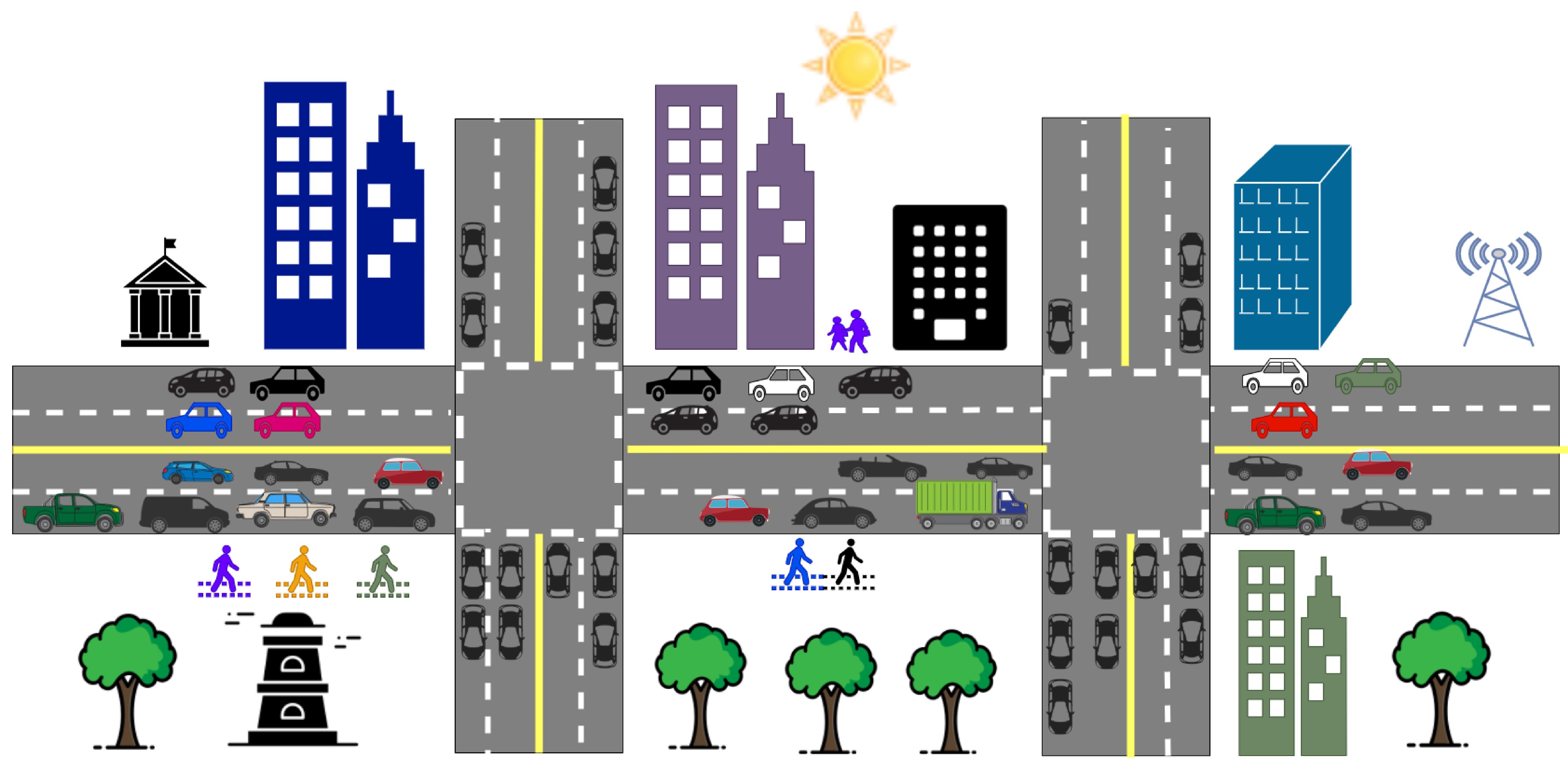

Fig 2. A schematic representation of an urban arterial

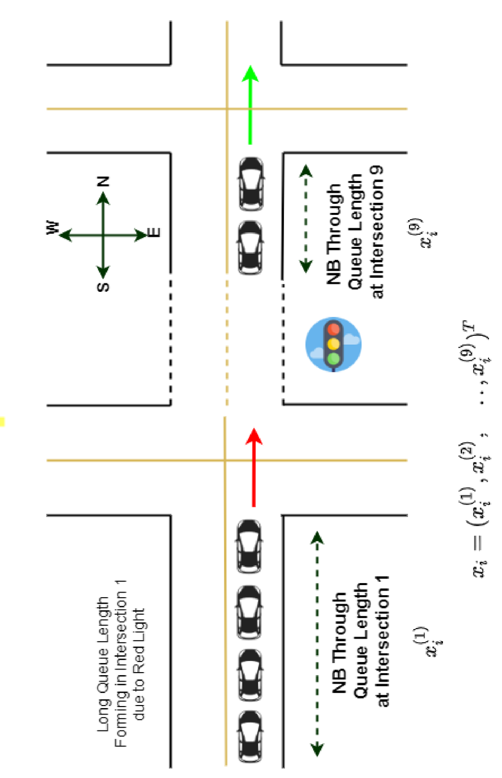

Fig 3 Queue length states space

Prediction and Reconstruction Results

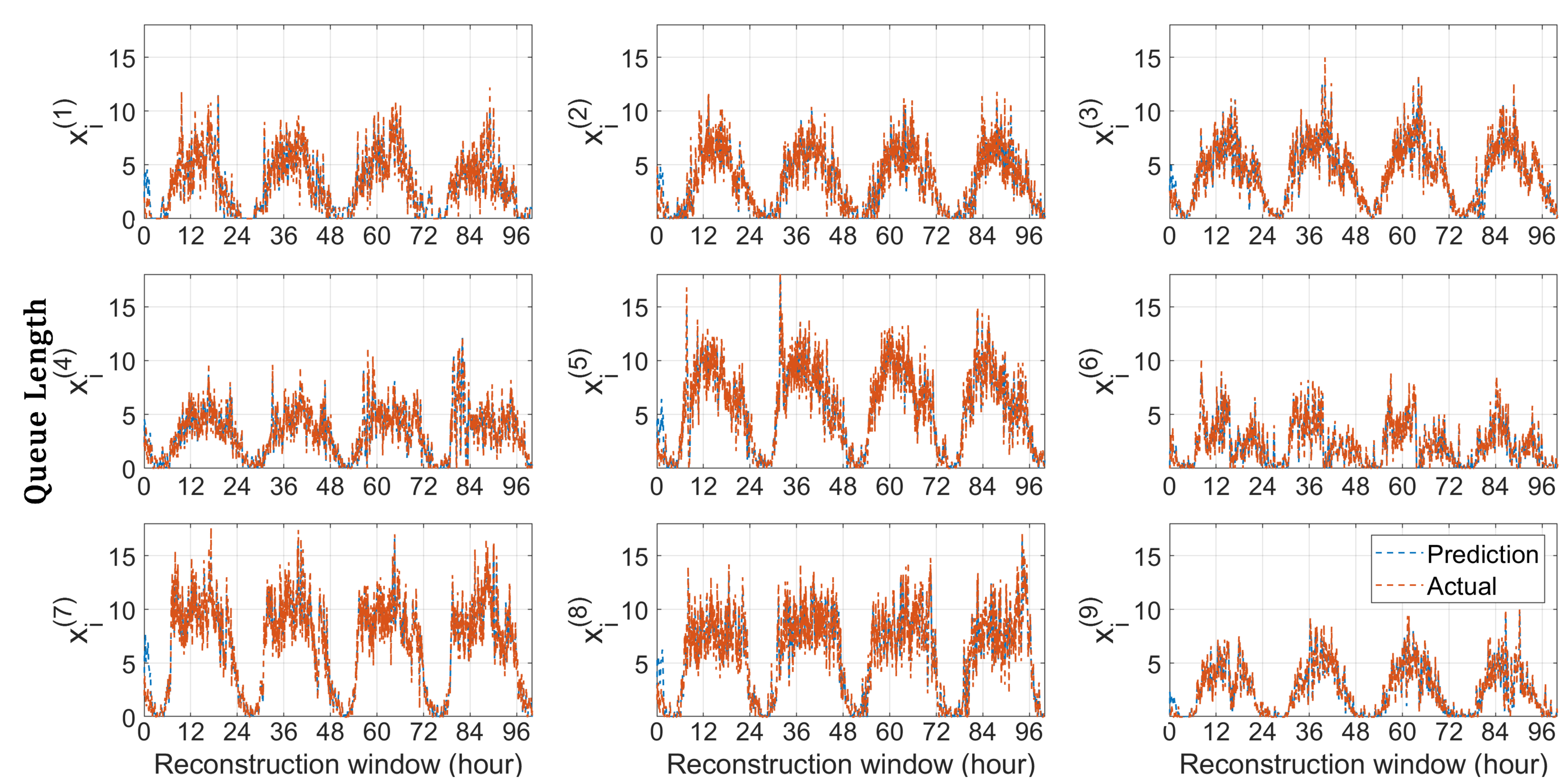

Fig 3. Reconstruction of queue lengths from historical data of the nine intersections shown in Fig 4.

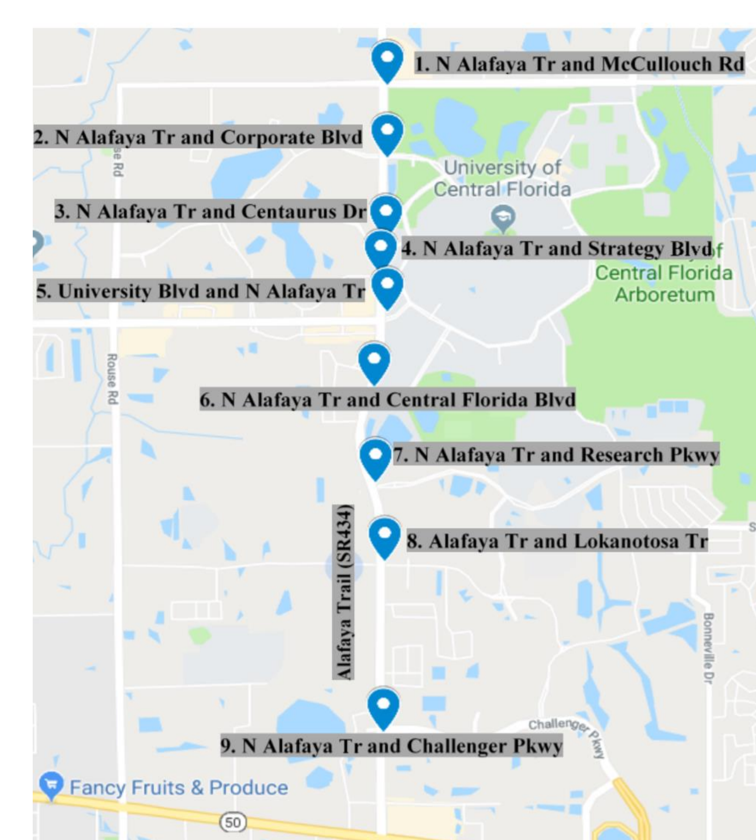

Fig 4. Alafaya Trail (Google Map)

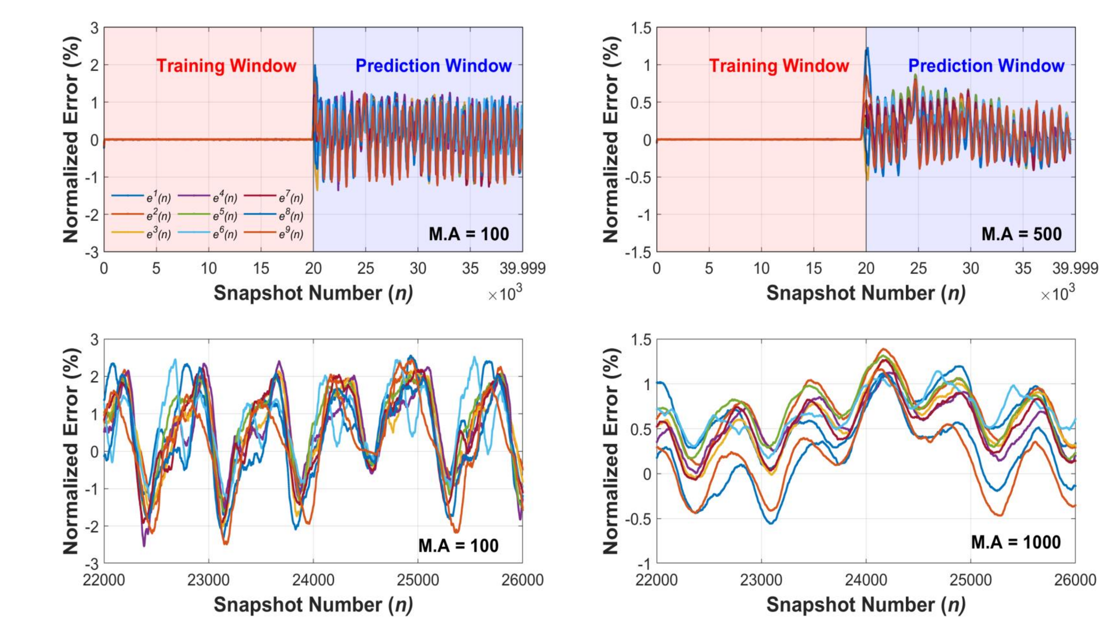

Fig 5. Prediction Error Analysis

Conclusion

- Generating frequencies identified by the technique were employed for stable prediction and reconstruction.
- The proposed technique also modeled chaotic components of the system and applied it for reconstruction and prediction.
- Unlike long short-term memory (LSTM) the long-term prediction errors remained bounded without any exogenous inputs.
- While black-box approaches such as artificial neural network (ANN), or LSTM lack interpretability, the proposed framework interprets the inherent quasi-periodic-type nature of signalized intersection corridor.
- An arxived version of the paper can be found at : https://arxiv.org/abs/2109.08623

Shakib Mustavee is a Ph.D. student at University of Central Florida. His research interests include dynamical systems-based approaches, its applications in intelligent transportation systems and urban mobility.
Email: smustavee@knights.ucf.edu

Dr. Shaurya Agarwal is an Assistant Professor in Civil, Environmental and Construction Engineering Department at University of Central Florida. His research areas include Cyber-Physical Systems, Smart Cities, Connected and Autonomous Vehicles.
Email: Shaurya.Agarwal@ucf.edu

Research Website (Urbanity Lab):
https://www.cecs.ucf.edu/sagarwal/