Quantifying Adaptiveness in Signalized Intersections: A Novel Fractal Analysis Approach

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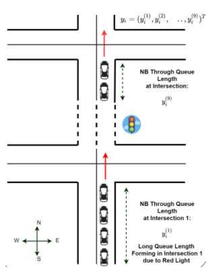
Introduction

- Adaptive signals dynamically modify signal timing in response to traffic fluctuations.
- Traditional metrics like waiting time and queue length offer performance assessments but lack detail on quantitative changes of the queue length dynamics.
- Our study employs fractal analysis on queue length time series from adaptive intersections.
- Our hypothesis is - adaptive signals introduce pink noise in the spectrum of queue length time series, serving as a tool to quantify adaptiveness.

Case Study

- Case Study: Nine adaptive signalized intersections selected along the Alafaya Trail near UCF, Orlando.
- Analysis focused on northbound traffic queue lengths, representing time series data recorded at each cycle.
- Metric for congestion: Over 25 vehicles waiting per cycle.



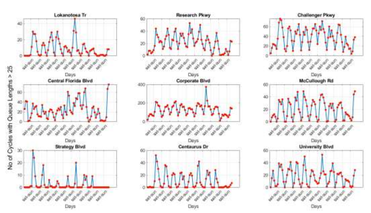


Fig 1(a). Queue lengths at Signalized intersections

Fig 1(b). Number of cycles with queue length> 25 (per day)

Power Law Characterization

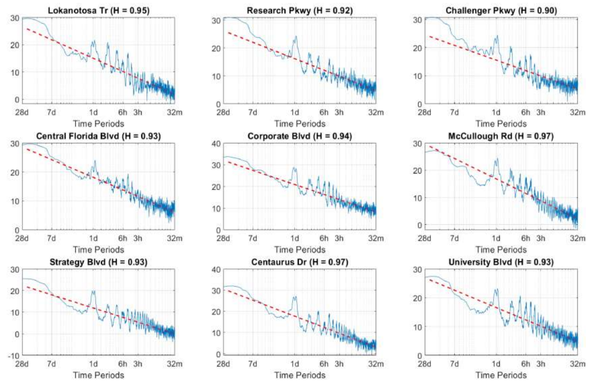


Fig 2. Power law in power spectral density of queue length time series

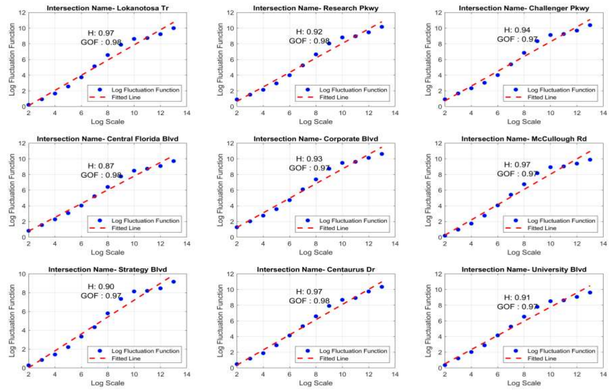


Fig 3. Detrended Fluctuation Analysis of queue length time series

Properties of Hurst Exponents

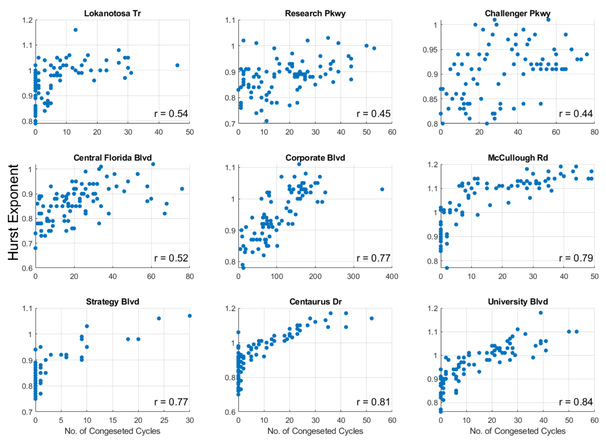


Fig 4. Correlation between fractal behavior and congestion

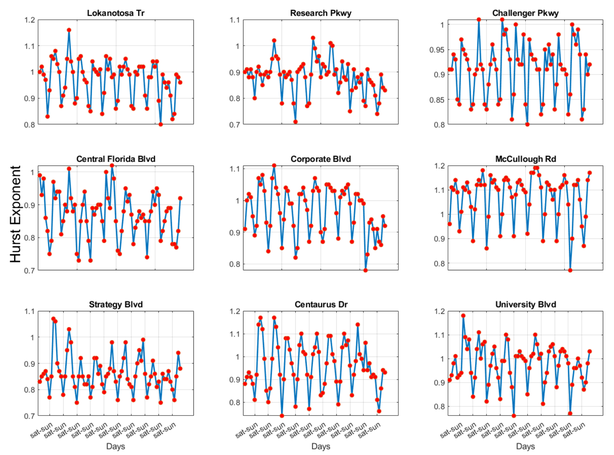


Fig 5. Periodic trends in fractal behavior

Key Findings

- Figure-2 shows that all northbound queue length time series display power-law behavior with an exponent near 1, indicating the presence of pink noise in their Power Spectral Density (PSD).
- Figure-3 shows that the time series adheres to the power-law trend up to 2^8 and enables Hurst exponent calculation from the slope.
- Figure-4 illustrates that Most intersections exhibit a positive correlation between Hurst exponents and congestion.
- Figure-5 demonstrate that Hurst exponents demonstrate both weekly and weekend trends.

Conclusion

- This study characterizes fractal behavior within queue length time series data for the first time.
- This research underscores the correlation between the Hurst exponent, a key metric for quantifying fractal behavior, and congestion levels at signalized intersections

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