Optimal Control applied to Urban Road Traffic

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Abstract. This article presents ongoing work on the application of optimal control strategies for signalized intersections in urban road traffic networks. A variant of the known TUC (Traffic-responsive Urban Control) strategy is developed and applied in simulation to a section of the city of Montevideo with good results in comparison with existing and good fixed-time strategies. Future work includes the implementation of this strategy in hardware-in-the-loop simulations with actual traffic controllers and field experiments in specific sections of the City where this strategy may bring clear improvements to the actual situation.

1 Introduction

Large cities are continuously looking for ways to extract the maximum from its road infrastructure. Many have invested in integrated solutions applying strategies like SCOOT, OPAC, PRODYN, [1] with good results. Technology development has brought down costs and made some solutions available to smaller cities. Innovative solutions have also been investigated using linear optimal control theory to mitigate congestion problems [2].

In a PDT project funded by the Uruguayan government and the International Development Bank, traffic controllers and signal control strategies are being developed with a view to apply them in the city of Montevideo. This City has an incipient centralized system, called Cité, with potential to handle complex strategies. Controllers and strategies are being developed to work together with Cité through a standard protocol called DIASER [3].

This article presents simulation results on the application of a extended TUC strategy to compute the green times, offsets to a section of the City of Montevideo. A model of the road and traffic of this area is developed and control strategies are implemented to run the experiments and comparisons are made with optimal fixed-time control.

2 Formulation, Implementation and Results

The TUC strategy is based on the assumption that a store and forward model of the network can be made, which can be translated to a discrete time linear system of the form:

$$x[(k+1)T] = x[kT] + \mathbf{B}\,\Delta g[kT] + \mathbf{D}\,\Delta d[kT]\,,$$

where the components of the vector x[kT] are the number of vehicles on each link at time kT, T being the sample time which can be no smaller than the cycle time of the network, matrices **B** and **D** reflect the network characteristics, the input vector $\Delta g=g-g^N$ is the variation of green times of each phase of each signalized intersection in the network with respect to their nominal values g^N while $\Delta d=d-d^N$ is the variation of demand flows with respect to its nominal value d^N.

Based on this model a linear quadratic regulator solution can be applied using a performance index J, given by,

$$J = \frac{1}{2}\sum_{k=0}^{K}\left(x[kT]^T Q\, x[kT] + \Delta g[kT]^T R\, \Delta g[kT]\right)$$

where **Q** and **R** are symmetric non-negative definite matrices, which leads to a feedback control strategy of the form $\Delta g[kT] = -L\,x[xT]$ to be computed at most once each cycle. This approach tends to balance the network load thus mitigating congestion. Since L is being precomputed, the amount of online computations does not explode with the network size and is reasonable with not so expensive systems. Offsets are updated using a proportional controller based on the times taken for vehicles between intersections.

A model of a section of Montevideo along the 8 de Octubre avenue close to the Universidad Católica is modeled with real data in the CORSIM microscopic traffic simulator. This area with 26 nodes and more than 50 links, presents congestion problems, spillback, etc. mainly at school hours and the city authorities are studying ways to solve it. This TUC variant is implemented using the real-time extension of CORSIM and several simulations are run using different demands. Figure 1 shows two screen captures of the model of the area during simulation. Best fixed-time, coordinated control is designed using TRANSYT to compare results as shown in Figure 2. Percentage of stop vehicles on links fall from 45 to 33 percent while average speeds increase from 23 to 31 km/h.

Fig. 1. CORSIM model and simulation of area of 8 de Octubre near Universidad Católica.

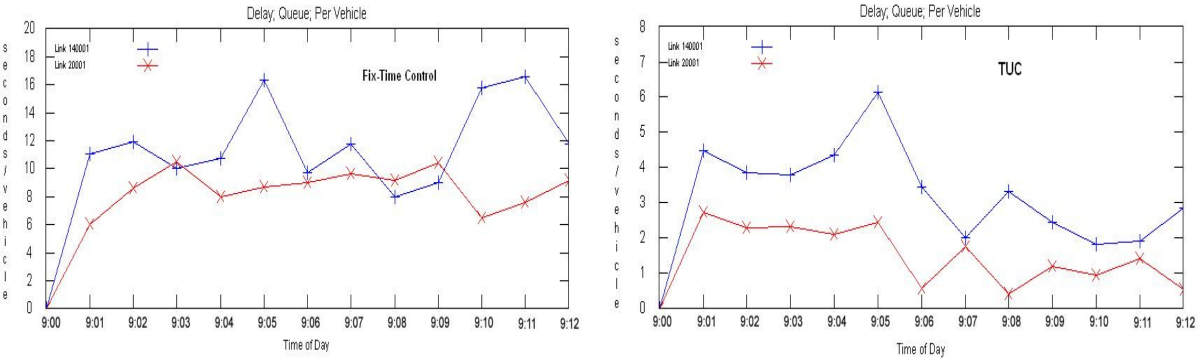

Fig. 2. Delay Queue per vehicle simulation results for fixed-time and TUC strategies.

In conclusion, first simulation results of the TUC strategy implemented compare well with respect to an optimal coordinated fixed-time control in speeds and stops on average while being more flexible to variations in the conditions. Still, more simulation cases should be analyzed to make a final assessment. It opens the path to implement these strategies in the traffic controllers designed for the PDT project, test them in hardware-in-the-loop simulations with CORSIM on this and larger sections of the city already modeled and finally on the field.

3 References

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