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A semi-decentralized control strategy for urban traffic

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Abstract

We present in this article a semi-decentralized approach for urban traffic control, based on the TUC (Traffic responsive Urban Control) strategy. We assume that the control is centralized as in the TUC strategy, but we introduce a contention time window inside the cycle time, where antagonistic stages alternate a priority rule. The priority rule is set by applying green colours for given stages and yellow colours for antagonistic ones, in such a way that the stages with green colour have priority over the ones with yellow colour. The idea of introducing this time window is to reduce the red time inside the cycle, and by that, increase the capacity of the network junctions. In practice, the priority rule could be applied using vehicle-to-vehicle (v2v) or vehicle-to-infrastructure (v2i) communications. The vehicles having the priority pass almost normally through the junction, while the others reduce their speed and yield the way. We propose a model for the dynamics and the control of such a system. The model is still formulated as a linear quadratic problem, for which the feedback control law is calculated off-line, and applied in real time. The model is implemented using the Simulation of Urban MObility (SUMO) tool in a small regular (American-like) network configuration. The results are presented and compared to the classical TUC strategy.

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Keywords: Traffic control, cooperative ITS, traffic modelling.

1. Introduction

Recent advances in information and communication technologies improve vehicular traffic in urban road networks by enabling the development of innovative urban traffic control strategies. While the traffic control in urban road networks is still done by setting traffic lights, intelligent transportation systems (ITS) are being tested in many cities. Various agents in the road network will be able to communicate from vehicle to vehicle (V2V) or from vehicle to infrastructure (V2I) for example. Big data sets, with different levels of information (microscopic, macroscopic) will be processed in real time and adaptive control strategies will be applied. The whole process of urban traffic control needs to be redefined in order to take into account this development.

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We think that several levels of information need to be distinguished in the big amounts of data that will be made available by ITS, and that the whole information cannot be optimally exploited with a unique centralized or distributed traffic control system. In our opinion, a multi-level control system needs to be developed in order to optimally use each level of information for the corresponding control level. Macroscopic information could be transmitted to the centralized controller, while the microscopic one could be used by the local controller, which should operate in a short time horizon, compared to the high-level controller. Multi-level control schemes have been recently proposed; see for example (Ramezani et al., 2015; Varaiya, 2013). In (Ramezani et al., 2015), the control uses macroscopic fundamental diagrams (MFD) (Geroliminis and Daganzo, 2007; Daganzo and Geroliminis, 2008; Farhi et al., 2005, 2007; Farhi, 2008, 2009; Farhi et al., 2011).

Using traffic lights, the main urban traffic parameters are: phase specification, split, cycle time, and offset. Fixed time urban traffic control (UTC) strategies appeared in the 1950s with coordination of signals that optimizes the offsets. These strategies use historic datasets, and therefore, are unable to adjust to changing conditions. The most well-developed and widely used UTC system is TRANSYT (Robertson, 1969). With advances in detection, communication, data processing, and control strategies, traffic responsive UTC systems appeared, where centralized and distributed systems are distinguished. Among the main centralized ones, we cite SCOOT (Hunt et al., 1981; Bretherton et al., 1998), SCATS (Lowrie, 1982), RHODES (Head et al., 1992), MOTION (Busch, 1996), and TUC (Diakaki, 1999). For distributed responsive UTC, we cite UTOPIA (Donati et al., 1984), PRODYN (Farges et al., 1990), OPAC (Gartner, 1991). Other UTC systems define an intermediate level of centralization.

Traffic responsive UTC systems use feedback controls on the state of the traffic and permit by that, to meet traffic demand. Moreover, the control may be set in such a way to be robust, in the sense that it responds rapidly to disruptions. Furthermore, such controls are automatically adaptive to works and operations, and so installation and maintenance costs are reduced.

We propose in this article an extension of the traffic responsive urban control strategy TUC (Traffic Urban Control) (Diakaki, 1999; Diakaki et al., 2002, 2003). Our extension introduces a kind of decentralization in the optimization of the right of way assignment. We introduce a contention time window inside the cycle time, where the traffic light is yellow for antagonistic stages that alternate a priority rule during this time period. A TUC-based centralized control determines the optimal split of green, red and yellow lights at the levels of every junction. A decentralized system manages the traffic of antagonistic stages during the yellow signal, taking into account the characteristics of each junction. By doing this, we aim to reduce the red time inside the cycle, increase the capacity of the network, and reduce users' delays. The traffic management during the yellow times would be realized based on vehicle to vehicle (V2V) and/or vehicle to infrastructure (V2I) communications. We present in this article preliminary results of this semi-decentralization on a small American-like city. The results demonstrate the efficiency of this extension with respect to the classical TUC control. On a selected scenario of traffic demand, we show that the semi-decentralized TUC controls better the traffic, in the sense that it is able to respond efficiently and rapidly to congestion.

2. A short review of TUC

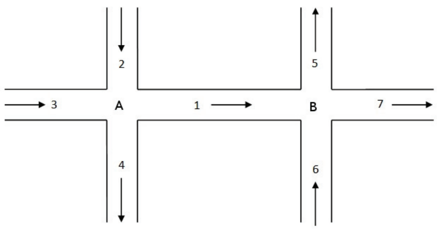

Fig. 1. Academic example explaining the TUC strategy.

TUC (Diakaki, 1999; Diakaki et al., 2002, 2003) is a coordinated control strategy based on a store-and-forward approach. It can be implemented for large-scale networks, in real time, even under saturated traffic conditions. The split control part of TUC varies the green-stage durations of all stages at all the junctions of a urban network around