ADAPTIVE SIGNAL CONTROL: AN OVERVIEW

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EXTENDED ABSTRACT

Urban road networks serve a significant part of traffic demand. For example in Germany ca. 30% of some 600 billion car kilometres per annum are travelled within metropolitan road networks. Because of the high demand many urban road facilities are frequently oversaturated and respectively congested. Through congestion the capacity of the road infrastructure is in fact reduced and particularly during rush hours when the maximum capacity is most urgently needed the performance deteriorates considerably.

Given the demand, the most efficient means to alleviate congestions and its negative impacts on travel times, as well as on environmental pollutions and on traffic safety is to balance the saturation of the different parts of the network. In urban road networks this goal is to be achieved primarily by the means of adaptive signal light control. In over thirty years of research and development different generations of adaptive control methods were developed and, to a certain extent, some of them are now established. Although these methods are operating successfully there is still a high potential for further improvements and accordingly research further concentrates on the development of more precise traffic models and more efficient optimisation algorithms.

The purpose of this paper is to give an overview on the development of most relevant adaptive control methods within the last decades, to discuss the traffic models and control algorithms they are based on, to document the results of field tests and simulation studies and last, but not least, to focus on the most recent research in this field.

By the help of a simple theoretical example the paper introduces the principle of adaptive signal control and explains to which extent this class of methods (in comparison to actuated control) can lead to a better usage of road capacity and thus can help to ameliorate traffic conditions in urban road networks.

The principle of adaptive control was first used by Miller (1963) when he proposed a strategy that is based on a online traffic model. The model calculates time wins and losses and combines this criteria for the different stages in a performance index to be optimised. In sequence a series of adaptive methods were developed. A prominent example of the so-called first generation of traffic adaptive strategies (which were not really adaptive) is PLIDENT (Holroyd et al., 1971). In the late 60's PLIDENT was implemented in Glasgow and failed.
Field trials with other first generation strategies in Canada (Corporation of Metropolitan Toronto, 1976) as well as in the frame of the UTCS programme in the United States (MacGowan et al., 1980) also failed due to inaccurate demand forecasts for longer time periods, slow reactions and capacity losses caused by transition programmes.

Hunt et al. (1981) analysed the shortcomings of the 1st generation strategies and overcame the problems by a more advanced 2nd generation strategy. SCOOT minimises delay by the smooth adaptation of split, cycle time and offset. In contrast to general believing only the offset is optimised on the basis of delay modelling whereas split and cycle time are adapted according to a saturation criterion. With successful trials of SCOOT in different networks resulting in savings of about 12% delay the break-through of adaptive methods succeeded. SCOOT is at present the most established control method with over 170 implementations all over the world.

In the early 80's a number of advanced so-called 3rd generation strategies have been developed, e.g. OPAC (Gartner, 1982) or PRODYN (Henry et al., 1983). These strategies are operating acyclic, i.e. they do not consider explicitly cycles or offsets. Given pre-specified stage schemes optimal switching times over a horizon are calculated. The optimisation is based on delay criteria determined by simple but fast running traffic models. For the global optimisation of the performance function OPAC employs complete enumeration whereas PRODYN uses dynamic programming. Due to the exponentially increasing complexity of the solution for more than one intersection real time implementations are only feasible for isolated intersections.

In order to consider network effects SPOT/UTOPIA (Donati et al., 1987) decomposes the control problem. Based on a similar principle as OPAC or PRODYN for local control SPOT gathers additional information on arriving vehicles by communication between the single controllers. In order to consider the network effects constraints for each intersection controller are generated by the network component UTOPIA. BALANCE (Friedrich et al., 1994) uses a similar concept for decomposing the control problem but employs a cyclic control strategy.

Both strategies were validated by different field trials and demonstrated a considerable potential of improvement compared to fixed time control or traffic actuated strategies (e.g. Hounsell et al., 1996).

Despite the achievements there exists a challenge for further research and improvement of the state of the art strategies. On the one hand the traffic models employed are, due to online requirements, rather simple. On the other hand the decomposition of the control problem only allows for a heuristic optimisation. Accordingly different ongoing research envisage following solutions:

A more traditional oriented research path is followed by the enhancement of traffic models and optimisation algorithms within existing control concepts. For example BALANCE is improved by the employment of more efficient search algorithms (Mertz, 2001), improved
online OD estimation using additional information on signal timing (Matschke et al., 2001) and a new method to determine online the queue length (Mück, 2002). The method of Mück can be understood as a online queue measurement and thus can be combined with Kalman filtering technique to correct the traffic model.

An alternative conceptual approach is chosen by Dürr (2001) who applies an event oriented microscopic online simulation to model the performance criteria and employs genetic algorithms for the optimisation. However, it turned out that in spite of high processing power this strategy is not real-time feasible.

Another way is used by Diakaki (1999) who applies with the TUC strategy a store-and-forward based modelling in combination with a linear-quadratic control method that allows online operation even for large networks.

REFERENCES


