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METAHEURISTIC APPROACHES FOR COMPLETE NETWORK SIGNAL SETTING DESIGN (CNSSD)

Approcci meteaeuristici per la progettazione completa di reti di intersezioni semaforizzate

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ABSTRACT

In order to mitigate the urban traffic congestion and increase the travelers' surplus, several policies can be adopted which may be applied in short or long time horizon. With regards to the short term policies, one of the most straightforward is control through traffic lights at single junction or network level. The main goal of traffic control is avoiding that incompatible approaches have green at the same time. With respect to this aim existing methodologies for Signal Setting Design (NSSD) can be divided into two classes as in following described

Approach-based (or Phase-based) methods address the signal setting as a periodic scheduling problem: the cycle length, and for each approach the start and the end of the green are considered as decision variables, some binary variables (or some non-linear constraints) are included to avoid incompatible approaches having green at the same time (see for instance Improta and Cantarella, 1987). If needed the stage composition and sequence may easily be obtained from decision variables. Commercial software codes following this methodology are available for single junction control only, such Oscady Pro® (TRL, UK; Burrow, 1987). Once the green timing and scheduling have been carried out for each junction, offsets can be optimized (coordination) using the stage matrices obtained from single junction optimization (possibly together with green splits again) through one of codes mentioned below.

Stage-based signal setting methods dealt with that by dividing the cycle length into stages, each one being a time interval during which some mutually compatible approaches have green. Stage composition, say which approaches have green, and sequence, say their order, can be represented through the approach-stage incidence matrix, or stage matrix for short. Once the stage matrix is given for each junction, the cycle length, the green splits and the offsets can be optimised (*synchronisation*) through some well established commercial software codes. Two of the most commonly used codes are: TRANSYT14® (TRL, UK) (recently TRANSYT15® has been released) and TRANSYT-7F® (FHWA, USA). Both allow to compute the green splits, the offsets and the cycle length by combining a traffic flow model and a signal setting optimiser. Both may be used for coordination (optimisation of offsets only, once green splits are known) or synchronisation. TRANSYT14® generates several (but not all) significant stage sequences to be tested but the optimal solution is not endogenously generated, while TRANSYT-7F® is able to optimise the stage sequence for each single junction starting from the ring and barrier NEMA (i.e. National Electrical Manufacturers Association) phases. Still these methods do not allow for stage matrix optimisation; moreover the effects of stage composition and sequence on network performance are not well analysed in literature.

Both methodologies described above share a two-step optimisation structure: decisional variables are first grouped in two sets, then sequentially optimised. No one-step optimisation method for the simultaneous optimization of green times,

their schedule, and node offsets, the so-called *scheduled synchronization*, is already available to authors' knowledge.

The research herein presented provides a methodology for one-step Stage Sequence Optimisation in Network Signal Setting Design. Whichever is the optimisation method, a within day dynamic traffic flow model is required. In this thesis an innovative Traffic Flow Model which allows for modelling both queuing spillback and platoon dispersion phenomena is also presented.

Formally, existing approach-based methods for single junctions may easily be extended to specify one-step methods for NSSD, since the node offsets may easily be obtained from decision variables, say the start and the end of the green of each approach, and if needed the stage composition and sequence as well. Nonetheless the resulting problem may be hard to solve since several equivalent local optima exist; this condition may quite easily dealt with for a single junction, but it is rather unclear how it can effectively be circumvented for a network (with loops). Thus meta-heuristics, or other optimisation techniques, might perform rather poorly unless the features of the space of solution are further exploited.

Stage-based methods can be used to specify one-step methods for NSSD by explicitly considering the stage composition and sequence as decisions. First, for each junction a set of candidate stages is defined then, the stage sequence can be optimised, as described with more details in section 2. Resulting methods are simpler than those derived from approach-based methods, but cannot provide the optimal solution in the general case.

The main contribution of the thesis is in developing a general methodology for one-step stage-based methods for Network Signal Setting Design; in particular a solution algorithms aiming at avoid explicit enumeration of stage sequences will be specified.