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Active control for traffic lights in regions and corridors: an approach based on evolutionary computation

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Abstract

The growth of vehicles’ fleet circulating on urban streets constitutes a very strong tendency in recent years. The main consequence of this phenomenon refers to the increase of urban congestions, of average delays caused by vehicles waiting on traffic lights and of number of stops. Finding strategies to achieve efficient active traffic control in urban centers is a challenge for engineers and analysts. Recently, important research on dynamic networks and Intelligent Transportation Systems using computational intelligence modeling techniques has been done. This paper proposes a new scheme of active control, using optimization algorithms, to dynamically find traffic signal control plans that optimize traffic conditions in delimited networks and corridors. The proposed system includes a time delay predictive model, used in conjunction with evolutionary approaches like genetic algorithms and differential evolution techniques. Conceptual and applied computational representations necessary for the construction of models are presented. Data collected from a big city in Brazil were fed into the commercial microscopic simulator AIMSUN and were used for the practical experiments. Two main experiments were undertaken and statistically compared in order to decide which method is more efficient in optimizing the active traffic signal timing control for the region under study.

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1. Introduction

The urban mobility system of urban centers in Brazil is characterized by intense use of motorized individual transport with all the effects that it represents in people's lives. According to data from ANTP (2012), the circulating fleet in 2012 was composed by 25 million vehicles, in cities with population over 60,000 people. In urban areas of these cities, about 210 million trips are carried out per day. In 2012 also, about 3.8 million cars were sold in Brazil.
These huge numbers are due mainly to the increase in people’s purchasing power in the country, the shortcomings of public transport and the lack of effective government actions to improve public transportation infrastructure. If these conditions continue, the fleet of cars and motorcycles should double by the year of 2025, according to data from IPEA (2011). One of the main symptoms of this increase refers to the growth of urban congestion, and hence the increase of average travel times and delay times, lengthy car queues and high number of stops at traffic lights.

These data show that the adopted mobility policies are not enough to control problems caused by the increase in urban traffic. The situation in Brazil is not very different from what occurs in urban areas around the World. In view of this, in recent years, several studies on models of traffic, dynamic networks and important contributions to Intelligent Transportation Systems (ITS) have been done.

Within several existing ITS strategies, one approach of Active Traffic Management is highlighted in this study, namely an active control system for traffic lights timing (ACTL). This intelligent approach has the ability to dynamically manage recurrent and non-recurrent congestions, based on existing traffic conditions (Mirshahi et al., 2007). Active Traffic Management systems seek efficient ways to optimize traffic conditions during periods of intense traffic. In the literature, several Computational Intelligence (CI) techniques using evolutionary algorithms have been proposed for similar purposes. Some work will be briefly discussed here, due to their relevance in the field and to the global importance of the problems they tried to solve. Park et al. (1999) developed a method based on genetic algorithms (GA) to identify cycle lengths, green times, offsets and phase sequences. They were the first researchers to optimize these four basic signal timing parameters simultaneously with GA. Kwasnicka and Stanek (2006) presented a traffic control system based on simulation and optimization using GA. Masterton and Topiwala (2008) applied techniques based on agents and GA to optimize traffic lights. Costa et al. (2011) proposed a multi-objective formulation to optimize network traffic lights using a traffic model based on fixed time control plans. This paper is an extension of the work by Oliveira et al. (2010) and Costa et al. (2013), aiming to overcome the limitations found on those studies and continuing to contribute to the research on ITS.

The general objective of this paper is to present a mathematical and computational model for ACTL, independent on simulation to operate and to evaluate the provided solutions, which results on greater practical ability and ease of adaptation while being transferred from laboratory to the real world. It is intended to dynamically establish the best traffic light plans to different traffic conditions, using Differential Evolution (DE) algorithm and GA in the optimization process, satisfying the objective of minimizing the average delay time of vehicles circulating in intersections of the region. In order to validate the proposed model, experiments of ACTL on a region of the city of Belo Horizonte, Brazil, were undertaken and analyzed. One important contribution of this work is to evaluate the linking of conventional models of traffic control with CI techniques, such as evolutionary optimization methods, reducing consequences caused by intense vehicle traffic in urban centers.

As it's still not possible to perform the refeeding of the system with real-time traffic data for each time interval, the input data for the ACTL are obtained by means of traffic micro simulation. To simulate the dynamic operation of the system and to provide an environment in which is possible to perform active control, at each simulated time interval (i.e., cycle time), the algorithms receive flow data generated by the simulator and determine a traffic light plan for this period. The microscopic simulator for road traffic AIMSUN is used to run the simulation. The demand generated in the simulations, used for the experiments, is based on real data collected by the Transport and Traffic Company of Belo Horizonte (BHTrans). Experiments results will be objectively compared in order to decide which algorithm is the most efficient in optimizing the average delay time of existing vehicles in the simulations.

The paper is organized as follows: Section 2 presents related work, which are the basis for the development of this work. Section 3 describes the proposed mathematical and computational model, objective functions, involved variables and a computational representation adopted for the evolutionary algorithms. Section 4 describes the experiments realized; and Section 5 shows and discusses the results. Finally, Section 6 summarizes the main conclusions and remarks of the study.

2. Related work

Several studies on traffic signal control using evolutionary techniques can be found in the literature. GA have been widely used in traffic control systems to optimize traffic conditions (Teklu et al., 2006), (Hajbabaie et al., 2015). Roupail et al. (2000) conducted optimization of average travel times of a signalized region through
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