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Soft computing in big data intelligent transportation systems

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ABSTRACT

The academic and industry have entered big data era in many computer software and embedded system related fields. Intelligent transportation system problem is one of the important areas in the real big data application scenarios. However, it is posing significant challenge to manage the traffic lights efficiently due to the accumulated dynamic car flow data scale. In this paper, we present NeverStop, which utilizes genetic algorithms and fuzzy control methods in big data intelligent transportation systems. NeverStop is constructed with sensors to control the traffic lights at intersection automatically. It utilizes fuzzy control method and genetic algorithm to adjust the waiting time for the traffic lights, consequently the average waiting time can be significantly reduced. A prototype system has been implemented at an EBox-II terminal device, running the fuzzy control and genetic algorithms. Experimental results on the prototype system demonstrate NeverStop can efficiently facilitate researchers to reduce the average waiting time for vehicles.

1. Introduction

Big data is now becoming common sense and the widely applied research area during the past decades [1]. With the pace of industrialization and urbanization, there are many research fields such as genome sequencing [2], intelligent transportation systems [3,4], chip design [5]. In particular, due to the main traveling facility in the crowded city, the amount of the automobiles is increasing rapidly. Consequently the traffic problem gets more and more serious, which not only wastes resources and time, but also causes serious losses to the economy [6].

It has been proved that traffic problem causes 60 billion Euro losses in Germany each year. For example, Beijing, China, had a total of 4 million vehicles at the beginning of 2010 and increased another 800 K during the past years. Congestion can lead to an increase in fuel consumption, air pollution, and difficulties in implementing plans for public transportation [7]. It is also reported that the average length of the waiting cars is 70 km altogether in Germany. The annual financial cost of traffic congestion has swollen 97 billion and each day Germans burn approximately 300 million liters of fuel while idling in the heavy traffic. With the rapid developing of the economy and the explosive data scale of individual vehicles, China National Information Center announced that the car consumption was at an increasing speed of 13% and the total sale reached 5.80 million.

The intelligent transportation system problem is one of the important areas in the real big data application scenarios. A major problem causing the ineffective traffic scheduling is the explosive data scale of the car flow at the intersections. Traditional methodologies could not handle the tremendous data scale, therefore the automatic tuning problem is still pursuing by many researchers. To efficiently manage the traffic lights and further to reduce the average waiting time, in this paper we propose NeverStop, which is extended from our previous work [4] to manage both a single intersection and correlated area with multiple intersections. Unlike the conventional traffic management systems, NeverStop is able to detect the traffic flow information and then determines the intervals of traffic lights. Flexibility is one of the most primary critical principles during the design of NeverStop system. Besides determining the time of traffic lights dynamically, users can also customize their own schemes to fit special occasions and also can control the traffic lights instantly: for example, while encountering traffic accidents or bad weather. In particular, we claim following contributions of NeverStop system:

1. NeverStop obtains the information of the cars over passing the green traffic light and waiting for the red light using RFID devices.

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NeverStop sends the car flow data to remote central server that is deployed in EBOX II devices.
2. EBOX II device processes the data, and then figures out the delay-time of the traffic lights using the fuzzy control rule and genetic algorithms.
3. EBOX II collects the information of nearby intersections from the server, and adjusts the time. (If the NeverStop system is deployed in a single intersection, this step could be skipped).
4. NeverStop manipulates the intersection by switching the light or takes an adjustment according to information.

The remainder of this paper is decomposed as below. Section 2 summarizes the related study and the innovation concepts of the NeverStop system. In Section 3 we present the NeverStop system overview and implementations. Section 4 describes the fuzzy control method and genetic algorithm. Section 5 illustrates the test plans and experimental results. Finally we conclude the paper in Section 6.

2. Related work and motivation

The intelligent transportation system has been widely researched for decades [8]. In this section we review the related study, including the intelligent transportation system, fuzzy control, genetic algorithm and web services, respectively.

2.1. Intelligent transportation system review

Intelligent transportation system has been a major research area during the past decade [9]. Now sensors have been an increasingly important method in the intelligent transportation system design [10]. An algorithm for the implementation of short-term prediction of traffic with real-time updating based on spectral analysis is described in [11]. The prediction is based on the characterization of the flow based on modal functions associated with a covariance matrix constructed from historical flow data. The number of these modal functions used for prediction depends on the local traffic characteristics. Although the method works well for the examples in this paper using the lower frequency modes, it can be adapted to include modes of higher frequency, as traffic conditions dictate.

Prominent short-term forecasting methods use different empirical and theoretical techniques. The empirical approaches (nonparametric and parametric) employ statistical methodology and/or heuristic methods for traffic flow forecasting. The nonparametric techniques include nonparametric regression [12] and artificial neural networks (ANNs) [13–15]. Considering two broad classes of models, namely, empirical and evolutionary, the distinction between examples of these and spectral-based forecasting can be seen. Ref. [16] focuses on an algorithm for moving-object detection and tracking, given a sequence of distributed laser scan data of an intersection. The goal is to detect each moving object that enters the intersection; estimate state parameters such as size; and track its location, speed, and direction while it passes through the intersection.

2.2. Fuzzy control methodologies

There is a broad range of diverse technologies under the generic topic of intelligent transportation systems (ITS) that holds the answer to many the transportation problems. However, fuzzy control methodologies have not been widely used. For example, Ref. [17] presents a novel interval type-2 fuzzy controller architecture is proposed to resolve nonlinear control problems of vehicle active suspension systems. It integrates the Takagi-Sugeno (T-S) fuzzy model, interval type-2 fuzzy reasoning, the Wu-Mendel uncertainty bound method, and selected optimization algorithms together to construct the switching routes between generated linear model control surfaces. Ref. [18] presents an adaptive cruise control (ACC) method. The main features of this kind of controller are the adaptation of the speed of the car to a predefined one and the keeping of a safe gap between the controlled car and the preceding vehicle on the road. Linda and Manic [19] proposed to evaluate the spatiotemporal risk based on the combination of online nearest neighbor and fuzzy inference.

2.3. Genetic algorithms

Genetic algorithms are becoming popular and effective in solving complex mathematical and scientific problems, including [20–22]. In the intelligent transportation systems, genetic algorithms have been utilized to achieve minimize driving [23] or waiting time [4]. The route guidance system [24], which provides driving advice based on traffic information about an origin and a destination, has become very popular along with the advancement of handheld devices and the global position system. Since the accuracy and efficiency of route guidance depend on the accuracy of the traffic conditions, the route guidance system needs to include more variables in calculation, such as real time traffic flows and allowable vehicle speeds. As variables considered by the route guidance system increase, the cost to compute multiplies. As handheld devices have limited resources, it is not feasible to use them to compute the exact optimal solutions by some well-known algorithm, such as the Dijkstra's algorithm, which is usually used to find the shortest path with a map of reasonable numbers of vertices.

To solve this problem, Lin and Yu [23] proposes to use the genetic algorithm to alleviate the rising computational cost. The authors use the genetic algorithm to find the shortest time in driving with diverse scenarios of real traffic conditions and varying vehicle speeds. The effectiveness of the genetic algorithm is clearly demonstrated when applied on a real map of modern city with very large vertex numbers. Singh and Tripathi [25] provides a "real-time" traffic signal control strategy using genetic algorithms to provide nearoptimal traffic performance for intersections. Real-time traffic signal control is an integral part of the urban traffic control system and providing effective real-time traffic signal control for a large complex traffic network is an extremely challenging distributed control problem. Arunadevi and Johnsanjeevkumar [26] addresses the problem of selecting route to a given destination on an actual map under a static environment. The proposed solution uses a parallel genetic algorithm (PGA) implemented using High performance Cluster (HPC). Lee and Abdulhai [27] focuses on real-time adaptive signal optimization using genetic algorithms. The proposed adaptive signal system provides acyclic signal operation based on a rolling horizon real-time control approach. By applying random A^* algorithm, Zou and Xu [28] clears out the biggest obstruction between the genetic algorithm and dynamic route guidance of how to get the initial generation of genetic algorithm. The developed models and algorithms are implemented with local electronic map and their computational performance is analyzed experimentally.

2.4. Web based approaches

A comprehensive and presentable public transport information system is deemed invaluable for local residents and tourists all over the world. This is particularly necessary in view of the complex city structure and transportation system in Hong Kong. There are more than ten public transportation modes available, all with different operation schedules, fare structures, and routing characteristics. To assist commuters in making better use of public transport, the system needs to be not only user friendly and informative but intelligent enough to provide optimal route choices in terms of users' traveling behavior or preference as well.