Information Sciences 433–434 (2018) 70–95

Contents lists available at ScienceDirect

Information Sciences

journal homepage: www.elsevier.com/locate/ins

An artificial immune network to control interrupted flow at a signalized intersection

Ali Louati [a,c], Saber Darmoul [b], Sabeur Elkosantini [b,c,*], Lamjed ben Said [c]

[a] *Raytheon Chair for Systems Engineering, Advanced Manufacturing Institute, King Saud University, P.O. Box 800, 11421 Riyadh, Saudi Arabia*
[b] *Industrial Engineering Department, King Saud University, P.O. Box 800, 11421 Riyadh, Saudi Arabia*
[c] *University of Tunis, ISG, SMART Lab, 41, Avenue de la Liberté, Bouchoucha, Le Bardo, 2000, Tunis, Tunisia*

ARTICLE INFO

Article history:
Received 21 June 2016
Revised 16 July 2017
Accepted 23 December 2017
Available online 24 December 2017

Keywords:
Traffic signal control
Artificial immune network
Case-Based Reasoning
Reinforcement Learning
Adaptive control
Fixed-time control

ABSTRACT

To monitor and control interrupted flow at signalized intersections, several Traffic Signal Control Systems (TSCSs) were developed based on optimization and artificial intelligence techniques. Although learning can provide intelligent ways to deal with disturbances, existing approaches still lack concepts and mechanisms that enable direct representation of knowledge and explicit learning, particularly to capture and reuse previous experiences with disturbances. This article addresses this gap by designing a new TSCS based on innovative concepts and mechanisms borrowed from biological immunity. Immune memory enables the design of a Case-Based Reasoning (CBR) System in which cases provide a direct representation of knowledge about disturbances. Immune network theory enables the design of a Reinforcement Learning (RL) mechanism to interconnect cases, capture explicit knowledge about the outcomes (success and failure) of control decisions and enable decision-making by taking advantage of previous outcomes in reaction to new occurrences of disturbances. We provide a detailed description of new learning algorithms, both to create the case-base and to interconnect cases using RL. The performance of the suggested TSCS is assessed by benchmarking it against two standard control strategies from the literature, namely fixed-time and adaptive control using the Longest Queue First – Maximal Weight Matching (LQF-MWM) algorithm. The suggested TSCS is applied on an intersection simulated using VISSIM, a state-of-the-art traffic simulation software. The results show that the suggested TSCS is able to handle different traffic scenarios with competitive performance, and that it is recommended for extreme situations involving blocked approaches and high traffic flow.

© 2017 Elsevier Inc. All rights reserved.

1. Introduction

With the sustained pace of urbanization and growing mobility requirements, traffic monitoring and control in urban areas became a major concern for local transportation authorities. Ineffective or inefficient traffic control leads to congestion and accidents, with human casualties and severe damage to equipment and infrastructure [10]. Effective and efficient traffic management contributes to improve performance and to insure safety, especially when disturbances occur. Disturbances are

* Corresponding author.
E-mail addresses: alouati@ksu.edu.sa (A. Louati), sdarmoul@ksu.edu.sa (S. Darmoul), selkosantini@ksu.edu.sa (S. Elkosantini), lamjed.bensaid@isg.rnu.tn (L. ben Said).

https://doi.org/10.1016/j.ins.2017.12.033
0020-0255/© 2017 Elsevier Inc. All rights reserved.

situations related to abnormal, unacceptable, intolerable, or unsatisfactory traffic conditions, that can be described in terms of different kinds of attributes, including indicators related to traffic status and fluidity (e.g. queue lengths, waiting times, number of vehicle stops, etc.), causes of occurrence (e.g. traffic accidents, weather conditions), and context of occurrence (e.g. peak/off-peak hours). In such situations, signalized intersections may become bottlenecks of the highway network and the major source of traffic congestion. Traffic Signal Control Systems (TSCS) coordinate individual traffic signals at signalized intersections to achieve network-wide traffic operation objectives [43]. TSCSs determine decisions to be sent to traffic signals in order to better control the traffic flow. These decisions are related to the duration of phases (i.e. cycle times or duration of green and red signals) and to the sequence that governs phase transitions.

1.1. Disturbance management capabilities of TSCS

Several TSCSs were developed to control traffic flow at signalized intersections. They can be classified into two classes: pre-timed and actuated systems.

Pre-timed controllers are based on a fixed time strategy: the duration and sequence of all phases remain fixed and do not adapt to the dynamic state of the traffic at each lane of the intersection [9]. The signal timing-plan is developed off-line on the basis of historical traffic data and using statistical analysis and mathematical optimization methods [6]. Various theories and methods were applied to enhance the timing efficiency of traffic signals [28]. Yin [51] indicated that pre-timed (fixed) traffic signals are widely used in the developing countries due to the high costs of implementation and maintenance of real-time adaptive signal control systems. The author pointed out that further improvements of the performance of TSCS is still needed to improve their ability to detect and to react to changes in traffic conditions.

Actuated controllers, also called adaptive traffic control systems [39], are based on adaptive time strategies: the timing and/or sequence of traffic signals are adjusted in order to optimize either a single objective (e.g. minimize the total waiting time or delay of vehicles in queues at intersections), or multiple objectives (e.g. minimize total waiting time and maximize average speed). This adjustment is made based on the status of traffic at each lane of the intersection. This detection is achieved using traffic detectors, which provide information on the presence or absence of vehicles at intersections.

In literature, although some references have addressed urban traffic disturbance management [14], existing TSCS still offer limited support to deal with disturbances. Limitations stem from the lack of explicit models for the representation of knowledge related to disturbances. Limitations are also related to the lack of generic mechanisms, and integrated functions that provide support to issues, such as how to detect disturbances, and how to determine/adapt decisions to disturbances, not only in terms of signal timing and sequence, but also in terms of coordination between several intersections.

1.2. Learning in adaptive traffic signal control

Many authors were interested in applying artificial intelligence techniques to adaptive traffic signal control [7]. A particular interest has been given to machine learning techniques [31]. This interest stems from the belief that machine learning contributes to create intelligent systems that can capture and reuse knowledge about previous experiences with disturbances, such as symptoms, causes, context, consequences, decisions and outcomes. Reusing such knowledge would enable improving and accelerating reaction to future occurrences of similar disturbances. This belief lead to the investigation of learning paradigms, including (but not limited to) Case-Based Reasoning, Reinforcement Learning, and Artificial Neural Networks.

1.2.1. Case-Based reasoning

In the literature, only a few works have investigated the use of Case-Based Reasoning (CBR) for traffic control. De Schutter et al. [18] developed a Decision Support System (DSS) that combines a multi-agent system and CBR to select and evaluate possible decisions to control traffic in highways via variable message signs. Decisions include setting speed limits, showing dynamic route guidance, and opening shoulder lanes. Karim and Adeli [26] developed a DSS to support transportation authorities in managing the traffic in work zones, and in improving work zone safety. Different types of control decisions are evaluated according to the type of work and traffic to guide drivers through the work zone with adequate protection for the workers. Sadek et al. [37] developed a CBR system for freeway traffic routing. The system monitors the traffic flow on several roadway segments. The information received from various devices, such as sensors and closed circuit television, is used to detect disturbances. When an incident is detected, the system develops a routing strategy that optimizes the utilization of network capacity and helps drivers to avoid the disturbed roads. Elkosantini et al. [19,20] developed a bimodal traffic controller for signposted road-rail intersections. The main objective was to manage the existing infrastructure to relieve congestion, react to disturbances, and insure a safer and more convenient travel for people. Authors developed a CBR system, coupled with fuzzy set theory, where each case is associated to a situation (traffic status) and its regulation decision (timing schedules).

In this limited number of works, authors usually state that the case-base is created using expert knowledge [18–20]. However, authors do not specify how this knowledge is acquired and how the case-base is built. A famous technique called the Condensed Nearest Neighbor (CNN) algorithm was widely used in other CBR application domains to build and optimize the size of case-bases [34]. However, to the best of the authors' knowledge, this technique has not yet been applied to traffic

Download English Version:

https://daneshyari.com/en/article/6856715

Download Persian Version:

https://daneshyari.com/article/6856715

Daneshyari.com