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A dynamic and automatic traffic light control expert system for solving the road congestion problem

W. Wen

Department of Information Management, LungHwa University of Science and Technology, Taiwan, ROC

Abstract

Traffic congestion is a severe problem in many modern cities around the world. To solve the problem, we have proposed a framework for a dynamic and automatic traffic light control expert system combined with a simulation model, which is composed of six submodels coded in Arena to help analyze the traffic problem. The model adopts interarrival time and interdeparture time to simulate the arrival and leaving number of cars on roads. In the experiment, each submodel represents a road that has three intersections. The simulation results physically prove the efficiency of the traffic system in an urban area, because the average waiting time of cars at every intersection is sharply dropped when the red light duration is 65 s and the green light time duration is 125 s. Meanwhile, further analysis also shows if we keep the interarrival time of roads A, B, and C, and change that of roads D, E, and F from 1.7 to 3.4 s and the interdeparture times at the three intersections on roads A, B, and C are equal to 0.6 s, the total performance of the simulation model is the best. Finally, according to the data collected from RFID readers and the best, second and third best traffic light durations generated from the simulation model, the automatic and dynamic traffic light control expert system can control how long traffic signals should be for traffic improvement.

Keywords: Simulation system; Traffic light control expert system; Radio Frequency identification; Traffic congestion

1. Introduction

Traffic congestion has been causing many critical problems and challenges in most cities of modern countries. To a commuter or traveller, congestion means lost time, missed opportunities, and frustration. To an employer, congestion means lost worker productivity, trade opportunities, delivery delays, and increased costs. To solve congestion problems is feasible not only by physically constructing new facilities and policies but also by building information technology transportation management systems. A growing body of evidence proves that simply expanding a road infrastructure cannot solve traffic congestion problems. In fact, building new roads can actually compound congestion, in some cases, by inducing greater demands for vehicle travel – demands that quickly eat away the additional capacity. Therefore, many countries are working to manage their existing transportation systems to improve mobility, safety, and traffic flows in order to reduce the demand of vehicle use. By enhancing public transport, route guidance systems, traffic signal improvements, and incident management, congestion can be improved greatly. Of course, construction of new private bus way, expressways, or subway to increase these growth for easy travel has not kept pace. From a recent analytical statistics of the US department of transportation (2007), it is estimated that roughly half of the congestion is what is known as recurring congestion – caused by recurring demands that exist virtually every day, where road use exceeds existing capacity. The other half is due to non-recurring congestion caused by temporary disruptions. Four main reasons of non-recurring congestion are: traffic incidents (ranging from disabled vehicles to major crashes), work zones, weather, and special events. Non-recurring

E-mail address: wenwu@mail.lhu.edu.tw

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events dramatically reduce available capacity and reliability of the entire transportation system. Therefore, researchers have done many researches to increase capacity and remove bottlenecks.

Schaefer, Upchurch, and Ashur (1998) developed a simulation model for evaluating freeway lane control signing. The simulation results show that lane control has little influence on congestion. However, the region between heavy and medium traffic flow is sensitive to lane control. Chen and Yang (2000) and Chen and Yang (2003) have created an algorithm to find a minimum total time path to simulate the operations of traffic light control in a city. Stoilova and Stoilov (1998) also built a simulation model to measure the best of traffic lights to achieve low noise levels with optimal traffic management and environmental pollution. Grau and Barcelo (1992) and Messmer and Papageorgiou (1994) discussed the minimum of queue lengths in different intersections. Meanwhile, to aid traffic management systems, Nooralahiyan, Dougherty, Mckeown, and Kirby (1997) adopted a Time Delay Neural Network (TDNN) to classify individual traveling vehicles based on their speed-independent acoustic signature. Wen and Hsu (2005) designed a route navigation system with a new revised shortest-path routing algorithm and made a comparison of performance evaluation. Besides, many researches on how to avoid traffic congestion by using the shortest-path algorithm have been published Chabini (1998), Chabini (1997), Hoyer and Jumar (1994), Ikeda, Hsu, and Imai (1994), Ikeda and Imail (1994) and Maniccam (2006).

Moreover, the widespread use of information technology provides an opportunity to enhance the techniques of expert systems (ES), which help managers deal with fast changing environment at a human expert with high-quality performance. Expert systems have a variety of applications in many areas. Additionally, researchers have attempted to develop effective intelligent systems to assist managers in making decisions about how to solve various problems Liao (2002), Liu (1997), Maniccam (2006), Sheu (2006), Xia and Shao (2005), Yang and Recker (2005). Wangermann and Stengel (1998) proposed an intelligent aircraft/airspace system that provides better system performance, redundancy, and safety by using the overlapping capabilities of agents. Powerful and flexible multiple agents with the function of principled negotiations are communicated each other. The system gives aircraft and airlines greater freedom to optimize their operations than their have now. Wen and Yang (2006) developed a dynamic and automatic traffic light control system for solving the road congestion problem. They simulated a specific road, the Chung San North road in Taipei, Taiwan, to discuss whether a road simulation model can solve a congestion problem. Findle, Surender, and Catrava (1997) developed a flexible and general on-line method to determine whether the phasing as an intersection in given traffic flow scenarios needs a protected left-turn. In their study, a simulation model and was constructed to reproduce the effect of permitted left-turns at an intersection. For comparison purposes, a number of experiments were carried out. Their new approach has been proven to produce better intersection performance than the 50,000 rule over a significant range of traffic flows. Eriksson (1996) utilized a two-tier architecture, a client–server model, to build a straightforward expert system which was coded in HTML embedded Java Applet to communicate with a knowledge server in the back end. Some user-interface operations such as mouse dragging, display, and field checking, were put into the front-end machine that can provide rapid response. Fay (2000) described a railway dispatching system, which has a knowledge base in fuzzy rules of the IF–THEN type. The system adopts fuzzy reasoning to obtain train traffic control decisions. The study shows that by systematically making use of the knowledge of train dispatching, traffic quality can be improved and operation costs can be reduced. The above descriptions show that using an expert system combined with a traffic light control simulation model is a good idea for solving congestion problem. Therefore, our study focuses on traffic signal improvements to improve traffic congestion problem.

The remainder of this paper is organized as follows. Section 2 introduces the framework for the dynamic and automatic traffic light control expert system. Section 2.1 describes the description of a simulation model for controlling traffic signals. Section 2.2 gives definitions and notations for the simulation model. In Section 3, simulation analysis and results for improving road traffic problems are illustrated. Finally, some important conclusions and future work are discussed in Section 4.

2. The framework for the dynamic and automatic traffic light control expert system

The dynamic and automatic traffic light control expert system (DATLCES) is composed of seven elements: a radio frequency identification (RFID) reader, an active RFID tag, a personal digital assistance (PDA), a wireless network, a database, a knowledge base, and a backend server (see Fig. 1). The RFID reader detects a RF-ACTIVE code at 1024 MHz from the active tag pasted on a car. The active tag includes a battery so that it can periodically

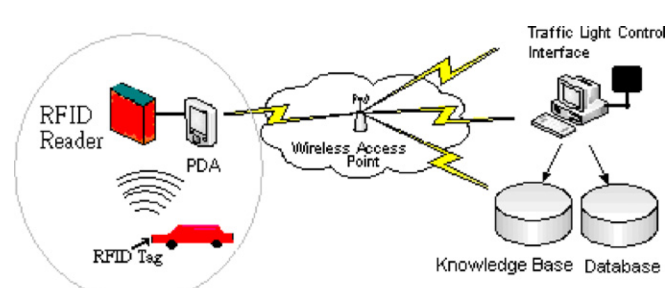

Fig. 1. A framework for dynamic and automatic traffic light control expert systems.