AN OPTIMAL ADAPTIVE TRAFFIC SIGNAL CONTROL ALGORITHM

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Bachelor of Electrical Engineering

July 2012

I hereby declare that I have read through this report entitle "**An optimal Adaptive Traffic Signal Control Algorithm**" and found that it has comply the partial fulfillment for awarding the degree of *Bachelor of Electrical Engineering (Control, Instrumentation, and Automation)*.

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Date : 29 June 2012

An optimal Adaptive Traffic Signal Control Algorithm

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A report submitted in partial fulfillment of the requirements for the degree of Electrical Engineering (Control, Instrumentation and Automation)

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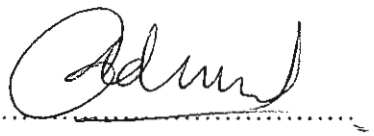
2011/2012

I declared that this thesis entitled "**An optimal Adaptive Traffic Signal Control Algorithm**" is the result of my own research except as cited in the reference. The report has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature : 

Name : ADELINE LUKAR HERLINO

Date : 29 June 2012

Specially dedicated to

my beloved family especially my father, Mr. Herlin Luthan

and my mother, Mrs.Asrani Sophia, lecturers, supervisor, classmate and people

who have guided me and inspired me throughout my journey of education

in Universiti Teknikal Malaysia Melaka.

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ABSTRACT

Traffic congestion arises for various reasons, and more than one mechanism is needed to combat it. One of the mechanisms that can be used to solve traffic congestion is a traffic light. This project about adaptive traffic signal control algorithm for the single intersection, which is believed to make real-time control signal and generate lots of traffic light switching scheme in accordance with change in traffic conditions. The principle of this algorithm is to minimize the mode of real-time queue length. The main objective of this project is to understand the principles of adaptive algorithm for single intersection and to design the traffic adaptive algorithm using C++ program. Using C++ program, the adaptive algorithm can be computed very efficiently.

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LIST OF SYMBOL

L_i	-	Lane i
T_i	-	The switches of traffic light
ADP	-	Adaptive Dynamic Programming
TD	-	Time Delay
RFID	-	Radio Frequency Identification
$\lambda_i(t)$	-	The arrival rate
$\mu_i(t)$	-	The departure rate
$\kappa_i(t)$	-	Respectively amber
δ_a	-	Amber
$l_i(t)$	-	The queue length
D_{12}	-	The distance between intersections
x_{max}	-	The maximum queue length
v_{12}	-	The average travel speed for vehicle
t_{12}	-	The travel time
T	-	The fixed cycle time
N	-	The integer

GA	-	Genetic Algorithm
PSO	-	Particle Swarm Optimization
ACO	-	Ant Colony Optimization
ELCP	-	Extended Linear Complementarity Problem

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CHAPTER 1

INTRODUCTION

An optimal Adaptive Traffic Signal Control Algorithm using Adaptive Algorithm is a project to design the programming of an intelligent traffic light control. The project is focused on the study of the adaptive algorithm for this intelligent traffic light control system. The simulation of the algorithm will be simulated by using Microsoft Visual C++ software to show the performance of the algorithm. This chapter will discuss about the problem statement, objectives and the scope of the project.

1.1 Problem Statement

Traffic congestion is one of the most common problems today. Congestion in some places makes the vehicles move slowly, and cause negative effects such as wasting time, a lot of fuel consumption and air pollution. The main objective is to reduce the average delay and average queue length, especially against the rush hour and accident around the traffic light area. An adaptive algorithm is one of the methods that can reduce average waiting times of cars.

Adaptive algorithm method is used to design the algorithm of traffic light. This method can be implemented in the event of a change of environment or any

circumstances in order to achieve the best possible outcome. In addition, the adaptive algorithm can be programmed in a number of computational languages to control traffic.

1.2 Objective

The objectives of this project are:

a) To study about adaptive algorithm in single intersection and multiple intersection.
b) To design the traffic adaptive algorithm using Microsoft Visual C++ Software.
c) To evaluate the performance of design algorithm for the traffic adaptive.

1.3 Project Scope

Even though the main objective this project to study about adaptive algorithm single intersection and multiple intersection but this project will be focused to design intelligent a traffic control system for single intersection with two-way streets, in a state of peak and off peak hour. This project uses a method of adaptive algorithm and the simulation will be done using Microsoft Visual C++ software, and no hardware involve in this project.

CHAPTER 2

LITERATURE REVIEW

In this chapter, a review of precious research projects that were related with this project will be discussed. The information about intelligent traffic light control using adaptive algorithm will be described in this chapter.

2.1 Introduction

One of the key elements to manage the transport network was traffic signal. There were many models of traffic control signals have been developed in the past. Current theoretical research on adaptive control signal has been ignored, many of which researches had applied intelligent techniques for expert systems and fuzzy logic. With the concern, the traffic signal control for intersections with two-way street has been studied.

2.2 Traffic Signal Control

Traffic control signals were implemented for the purpose of reducing the problem at the intersection, one of them was accidents at intersections. Besides these problems, there

were also caused by the intersection at an area shared between multiple streams of traffic, and the signal system that was used to manage the joint of the area. The signal function was used to control access to the intersection and allocate time among various traffic usages. The logic for this allocation can vary from simple time-based method to compute complex algorithms in real-time allocation based on traffic demand. This section provided an overview of the concept of traffic control signals.

2.3 Intersection Traffic Light

Traffic lights provided at the junction of two or more roads where there were two intersections of single and multiple intersections. Possibilities of intersection contained in a two-way street, 3-way Street such as T junction or fork junction, and 4-way such as a crossroads or more.

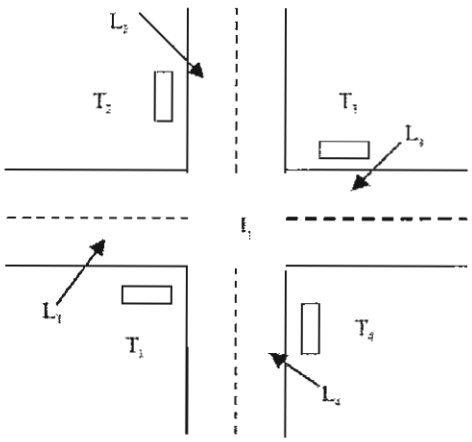

Figure 2.1: Typical intersections with two 2-way intersection [2].

Intersection of 2-way streets shown in Figure 2.1, the lane 1 (L_1) and lane 3 (L_3) had left turn lanes from both directions, but the lane 2 (L_2) and lane 4 (L_4) did not have left turn lanes at this intersection.

In paper [14] it had another intersection which were 3-way streets, 4-way streets or more intersection. For 3-way intersection, there was a junction between three roads segments, it was a T junction or a Y-junction such as two arms forms one road, shown in Figure 2.2.

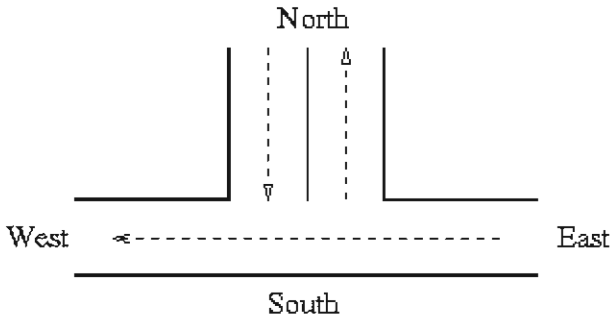

Figure 2.2: Typical intersections with two 3-way intersection [14].

4-way intersection was the most common, because it involved the crossing of two streets or roads. In areas, where there were blocks apart from that crossing streets or roads, were perpendicular to each other. 5-way intersection was rarely found but still exist in some places, especially in urban areas with non-rectangular blocks and another intersection.

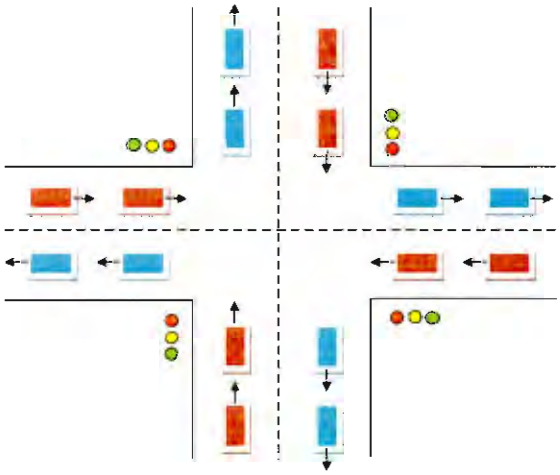

Figure 2.3: The subsystems of the intelligent traffic control system [13].

Al-Ani and Alheeti in [13], explained Traffic light control system of traditional / conventional intersection roads and it was shown in Figure 2.3. The red color was the vehicle

entering the intersection, and the color blue was a vehicle that left the intersection. Each vehicle has priority to enter the intersection and cross the street anywhere through the intersection. Any vehicle left the crossover blue, red vehicles could enter the intersection.

2.4 Intelligent Traffic Light

The intelligent traffic light was usually used in crowded cities, because of varieties in the flow of road vehicles during different time of periods and making it difficult to implement traffic control systems. These parameters must be taken into consideration to develop a specific traffic control systems, such as the flow of vehicles, emergency vehicles, rush hour, accidents, important people and the closure of any driveway. Such systems were typically used to design the traffic signal control systems for instance Fuzzy [8], Q-Learning [7, 9], Adaptive Dynamic Programming (ADP) [6], RHODES [3], RFID [11, 12], Adaptive Algorithm [1, 2, 11, 10], so forth.

Wen et al. as in [8] studied the use of fuzzy reinforcement learning (FRL) model to a stochastic adaptive traffic signal control. By using the FRL model, average total delay of each vehicle under the heavy demands compared with the scheme of FAC has been reduced 25.7%. The results of the FRL let the timely decisions in real-time in various traffic conditions.

Shoufeng et al. studied the use of Q-Learning for adaptive traffic signal control based on delay minimization strategy. Using this method, the results indicate that Q-learning for traffic control signal can reach a lower delay for variable traffic conditions [9]. The minimize delay become more time saving for the car and the accounting in low.

Lu et al. in [7] also used Q-Learning for adaptive traffic signal control based on delay minimization strategy, but this paper was explained incremental multistep Q-Learning ($Q(\lambda)$) from combine Q-Learning and TD (λ). The objective of this paper was to performance of $Q(\lambda)$

for adaptive traffic signal control, and the result Q(λ) algorithm did not demonstrate a better performance compared to Q algorithm.

Li et al. in [6] described an adaptive dynamic programming for multi-intersections traffic signal intelligent control. A new signal control method based on a model-free action-dependent ADP (ADHDP) signal controller was adapted to adjust the signal timing parameters according to the integrated, and the results shown ADP can reduce the average waiting time.

Mirchandani in [3] studied the use of RHODES a real-time traffic signal control system. Rhodes is used for a fixed control strategy based on signal-time plan is defined in terms of operating parameters for the control of traditional signals such as cycle time, splits and offsets. So, the control strategy of Rhodes is the emphasis shifted from changing the time parameters in response to traffic conditions observed only proactively setting phase durations for predicted traffic conditions.

Al-Khateeb and Johari in [11, 12], described the dynamic traffic light sequence algorithm using RFID. RFID technology is a technology with algorithms and data base then applied to multi vehicle, multi-lane and multi road junction area to provide an efficient time management schemes, and the dynamic management scheme operates in real time and emulates the judgment of a traffic policeman on duty.

Cheng et al. in [2] studied the use of adaptive algorithm for an optimal adaptive traffic signal control algorithm for intersections group. The principle of this algorithm is to minimize the real-time mode of queue length. It can show the average waiting time with the algorithm method is smaller than use the traditional method.

Cheng et al. in [1] also studied the use of adaptive algorithm for optimal green time for intersection group. The principle of the algorithm is to minimize vehicles delays. The new

algorithm has been used in Kunming city for traffic control signals at intersections group, the analysis showed that only increase the width of the "green wave".

Chen et al. in [10] studied the algorithm for the traffic light setting problem on the graph model. In this paper, the graph model is used to set waiting time of vehicles on the roads and the time is minimized. There are having three evolutionary algorithms which are GA, PSO, and ACO. The result for GA is more efficient and considered as good strategy to minimize the total waiting time of each vehicle.

Based on the previous studies, the traffic signal control systems such as Fuzzy [8], Q-Learning [7, 9], Adaptive dynamic programming (ADP) [6], RHODES [3], RFID [11, 12], Adaptive Algorithm [1, 2, 11, 10] can reduce the average delay, waiting time and average queue length, especially during the rush hour and accident around the traffic light. This project will be focused on the use the adaptive algorithm to minimize waiting time, and the information from all journals will be combined to make this thesis successfully.

CHAPTER 3

METHODOLOGY

This chapter described the methodology of this experiment. This project was involved developing programming software to design the adaptive algorithm. The literature study has been done, by collecting the data on the intelligent traffic light and adaptive algorithm. Afterwards, the programming can be started to show the performance of the algorithm in controlling the traffic light system, if the suitable algorithm for the system was found.

3.1 Developing an Algorithm

Algorithm can be used for queue lengths of traffic lights developed by the switching scheme based on queue length and the average waiting time, the method was extended to the intersection group.

Figure 2.1 showed the intersection. There were four lines, which were L_1, L_2, L_3, and L_4 and four traffic lights, which were T_1, T_2, T_3, and T_4. It also had three phases: red, yellow, and green.

In line L_i, the arrival rate of vehicle at time t could be defined as $\lambda_i(t)$ and the departure rate could be defined as $\mu_i(t)$ while amber was defined as $\kappa_i(t)$, for $i = 1,2,3,4$. For the duration of the amber phase was fixed as δ_a and the queue length was $l_i(t)$, obviously $l_i(t)$ must be greater than zero for all i and t.

Table 3.1: Traffic light switching scheme.

Period	T1,3	T2,4
t_0-t_1- δ_a	Red	Green
t_1-δ_a-t_1	Red	Amber
t_1-t_2- δ_a	Green	Red
t_2-δ_a-t_2	Amber	Red
t_2-t_3- δ_a	Red	Green
t_3-δ_a-t_3	Red	Amber
t_3-t_4- δ_a	Green	Red
t_4-δ_a-t_4	Amber	Red
t_4-t_5- δ_a	Red	Green
t_5-δ_a-t_5	Red	Amber

From Table 3.1, the traffic lights T_1 and T_3 switch from amber to red and then T_2 and T_4 switch from red to green, it can be assumed that t_0, t_2, t_4, is the time instants. Furthermore, the traffic lights T_2 and T_4 switch from amber to red and then the traffic lights T_1 and T_3 switch from red to green, it can be assumed that t_1, t_3, t_5 is the time instants.

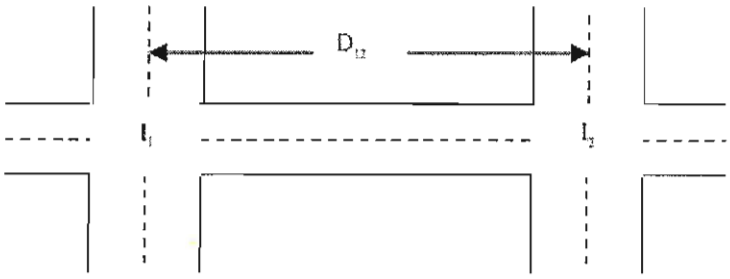

Figure 3.1: The typical of two 2-way streets in two intersections [2].

Figure 3.1 showed the combination of typical intersection and the distance between intersections one and intersections two was D_{12}, one of intersection was I_1, and another intersection was I_2.