FUZZY LOGIC BASED EFFICIENT TRAFFIC CONTROLLING SYSTEM FOR REGULATING THE TRAFFIC CONGESTION IN METROPOLITAN ROAD JUNCTIONS

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INTRODUCTION

Problem

Today, transportation is one of the vital needs of day to day life. Inland transportation is widely used all over the world. As a result of development, industrialization and personal requirements traffic congestions often occur on the city roads due to the increase of the vehicle usage by the people. Sri Lanka highways also face this problem. As in other countries Sri Lanka is also using Traffic Light Controlling Systems to regulate the existing traffic congestion. Even though these Traffic Light Controlling Systems are in operation, in many busy junctions, these systems fail to regulate the traffic flow. The reason is that, these existing systems are controlled based on fixed time cycles.

Road traffic is a real time problem and sometimes this prior information is not sufficient to control the existing road traffic. Although the automated traffic controlling system is available, today it can be easily noticed that the human intervention is required to smoothen the traffic congestion on the busy junctions in most Sri Lankan cities.

Objectives

The proposed solution will be able to intelligently make the possible decisions regarding the current road traffic congestion and it will be able to regulate the existing road traffic congestion without having any human intervention. In addition to that, this proposed system will be able to minimize the unnecessary waiting period and furthermore it will be able to improve the efficiency of the existing traffic controlling system.

Background

A research conducted recently has clearly stated that Fuzzy Logic based approaches are capable of improving the vehicle throughput and minimize unnecessary delays in highways (Kulkarni and Wainganka 2007). This research was done based on isolated junction with vehicle actuated controller. Vehicle actuated controlling systems are used in Sri Lanka and it is better to consider the applicability of rule bases for above mentioned requirement. Further, it has been identified that the precise prediction of traffic condition in immediate future is not possible and the control action is based on optimizing the current status only. Thus, the control action may not yield optimal condition in the long term (Trabia, Kaseko & Ande 1999).

Modeling the intelligent traffic controlling component which is named as "Fuzzy Engine" (FE) was the major task of this research. This newly proposed system is capable of calculating the efficiency of the intelligent traffic controlling and it will be presented as a proof of adaptability of this new system. Initially the FE will be evaluated using a simulation environment.

METHODOLOGY

Data gathering and analysis

Initially this system will be proposed for the existing traffic controlling system which has been implemented in a four way junction to smoothen the traffic congestion based on two phase traffic control pattern (Aziz 1996). Filed observation and interviewing the authorized stakeholders of the existing system was carried out as the data gathering techniques. The Length of the vehicle queue, frequency of vehicles arriving at the junction, types of vehicles and number of turning patterns in the junction were identified as the important factors to design the FE during the analysis phase.

FE design issues

Mainly there are two input linguistic variables that were identified for designing the FE; namely the percentage of traffic region usage (REDQ) and the number of vehicles moving across the junction (GREENQ). REDQ is maintained under the red light of the traffic light post and GREENQ occurred under the green light of the traffic light post. REDQ is distributed within the traffic region of one road of the four way junction in a certain traffic cycle time. The scope of the REDQ can be represented as $0 <= (REDQ) <= 100$. The scope of the GREENQ can be represented as $0 <= (GREENQ) <= 60$. The scope range is determined by considering the vehicle arrival frequency simulated in the simulation environment. The length of the vehicles simulated within the simulation environment is considered as fixed. The output linguistic variable of the FE is denoted as probability of changing of next cycle time (CHANGET). The scope of the CHANGET can be represented as *0<= (GREENQ) <=1*.

Triangular and trapezoid membership distributions were used to model the defined fuzzy sets under the input and output linguistic variables and the fuzzy sets and membership distribution parameters were selected by analyzing a series of photographs taken under the different traffic conditions. REDQ consists of four membership sets named as *less, moderate, half* and *full*. GREENQ consists of three membership sets named as *less, considerable* and *many*. CHANGET consists of three membership sets named as *maybe, possible* and *yes*. In a fuzzy inference engine, fuzzy input and output membership functions are combined to form a series of fuzzy IF-THEN rules to make the final judgment. There are eight rules available in the proposed FE rule base. Center of Gravity (COG) method is used in the FE to obtain the de-fuzzification value. This method determines the centre of the area of the combined membership functions which means it calculates the centroid or COG of combined output membership functions as figure 1.

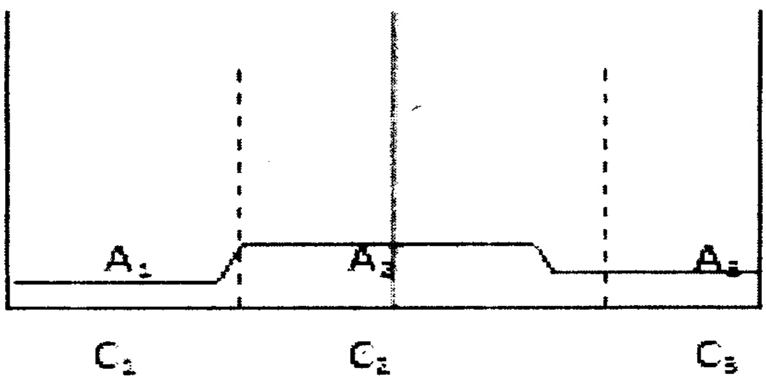

Figure 1 – Combined output membership functions

The equation used to calculate COG;

$$COG = \frac{\sum A_i \times C_i}{\sum A_i} \text{ When } 0 \leq i \leq 1 \qquad \text{(equation 1)}$$

Where,
A_i = Area of the i^{th} output membership function.
C_i = Center of the i^{th} output membership area.

RESULTS AND DISCUSSION

The FE was integrated with the developed simulation environment and proposed system architecture of the system is depicted in the figure 2. Main Simulation Screen (MSS) represents the existing road traffic controlling system based on a four way junction and Intelligent Layer (IL) represents the placement of proposed FE. Default time cycle of the MSS has been set as 2*ms*. Log Manager (LM) component of the Log Management Layer (LML) records traffic details of the simulation and MSS was used several times under selected traffic conditions to check the adaptive behaviour of the FE.

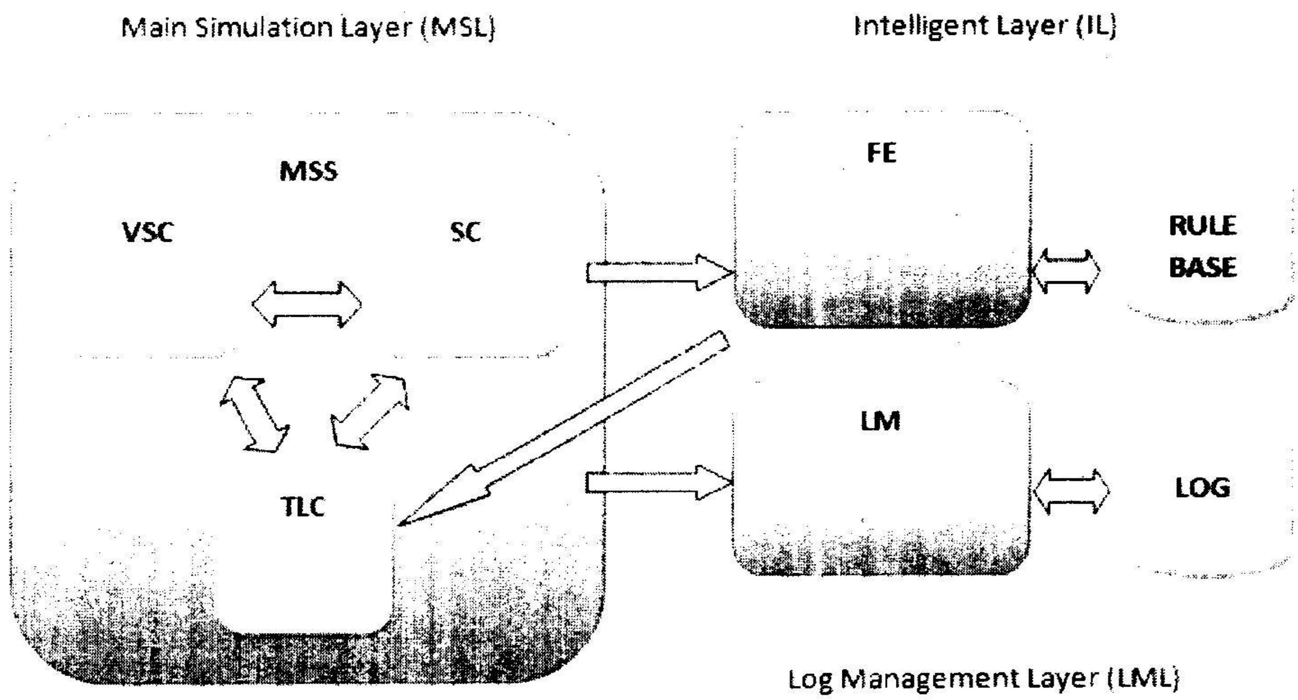

Figure 2 – Proposed system architecture

MSS –Main Simulation Screen VSC-Vehicle Simulation Component SC-Sensor Component
TLC-Traffic Light Component FE-Fuzzy Engine LM-Log Manager

Data recorded in the LM is used to analyse the efficiency of the traffic regulation and it was calculated using the following formula;

$$\boldsymbol{Efficiency\ of\ trffic\ regulation} = \frac{\boldsymbol{Number\ of\ Fuzzy\ time\ cycles}}{\boldsymbol{Total\ number\ of\ time\ cycles}} \times \mathbf{100}$$

Table 1 depicts the sample test traffic conditions set in the MSS to test the adaptability and efficiency of the traffic regulating using the FE. Table 2 depicts the traffic data recoded by the LM during the simulation with respect to the traffic conditions shown in the table 1.

Table 1 : Test Traffic Condition set in the MSS

Direction	Total # Vehicles	Remarks
North	120	High Traffic
South	100	Medium Traffic
East	40	Low Traffic
West	10	Low Traffic

Table 2 : Data recorded by the LM

Date Time 11/12/2011	S1	S2	S3	S4	S5	S6	S7	S8	Fuzzy Time	Cycle Time (ms)
4:47:55 PM	0	0	1	0	0	0	0	0	0	2.0
4:48:03 PM	13	2	15	2	40	40	10	10	0.1	1.8
4:48:12 PM	59	45	55	45	40	40	10	10	0.3	2.6
4:48:20 PM	61	47	60	47	40	40	10	10	0.1	1.8
4:48:28 PM	109	100	87	80	40	40	10	10	0.1	2.2
4:48:37 PM	110	104	88	82	40	40	10	10	0	2.0
4:48:45 PM	120	120	110	110	40	40	10	10	0	2.0

According to the results shown in table 2, there were seven traffic cycles occurred during the simulation and four out of seven traffic cycles was recorded as fuzzy traffic situation. Traffic data related to the fuzzy traffic cycles were shaded in the table 2 and the cycle time for those fuzzy traffic cycles were deviate from default cycle time (2ms) according to the decisions made by the FE. The efficiency of the traffic regulating related to the above simulation data was nearly 57% more efficient than the conventional fixed time based traffic controlling. According to the above data it can be concluded that the intelligent traffic controlling is thoroughly required when the traffic is distributed unequally within the junction and if there is a clear difference between the total numbers of vehicles in each road depending on the traffic condition.