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Performance of adaptive-fuzzy technique in controlling vehicular traffic

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ABSTRACT

A vehicular traffic control system was designed with an inexpensive OOPIC micro controller. The information on vehicular traffic at the junction was simulated and fed to the microcontroller and was used as the primary input for the decision-making algorithms.

The adoptive algorithm first compares the number of vehicles in a chosen lane with those present in all other lanes at any given moment. The ratio between number of vehicles was calculated and the moment the ratio fell below a pre-defined threshold value, changes in traffic signal times were sought through a fuzzy sub-system. The algorithm 'learns' continuously and converges to the most acceptable switching time for each lane on a particular day at a particular time.

The pilot tests indicated that the system efficiency improves with time as it continues to learn from experience. It was observed that on average the system adapts itself to a new situation within two or three cycles. Even when the change in traffic pattern is small, 20%-30% efficiency improvement was seen in this system compared to a programmed time system. For a large change, the improvement was about 60%. In worse case scenario, (such as a failure of a sensor), the system behaves as a programmed time system.

1. INTRODUCTION

Controlling traffic is a critical task in safe and efficient operation of any transportation system. Elaborate operational procedures, rules and laws, and physical devices (*e.g.,* signs, markings, and lights) are some of the components used in any traffic control system. While traffic control can be considered as a need to control or influence large numbers of vehicles, it is important to realize that traffic is made up of a large number of individual operators who collectively must make consistent decisions in order for the systems to function safely and efficiently.

In Sri Lanka, due to rapid increase in the import of vehicles especially in the recent years and the absence of proper road infrastructure to accommodate the increase, vehicular traffic has become a major problem for many commuters.

There are three basic types of traffic control systems. They are,

1. *Fixed time traffic control systems:* The time interval for each of the lanes is the same. This system assumes that the volume of traffic is same in each lane. Since this is not the situation in most of the junctions, it does not work well with the changes in the traffic patters throughout the day.
2. *Programmed time traffic control systems:* A system based on physical surveys conducted on traffic at a given junction. They are pre-programmed to allocate time periods for each lane depending on the hour of the day. However, even these systems are too rigid since the averages do not represent the actual need for any given time.
3. *Remote video traffic control systems:* An advance system that use video cameras to assess the volume of traffic on each lane and manipulate traffic timing remotely to obtain smooth flow of traffic at a junction. However, these systems are fairly expensive. Moreover, the operator's efficiency can suffer with time due to the monotonous nature of the work.

There are several other traffic control system than those discussed above. They are traffic control systems based on Neural networks, Fuzzy logic and Neuro-Fuzzy logic. After the fuzzy theory invented by Zadeh (1965), it is now used widely for *inference* and *control* especially in problems like traffic control. None of these modern techniques are used in any of the present traffic control systems implemented in Sri Lanka. The main purpose of this work is to explore the suitability in using some of these techniques for traffic control.

2. THEORETICAL BACKGROUND

2.1 Software concepts

Any smart traffic control system should have the ability to learn from experience. In this work, two concepts, adaptive techniques and fuzzy logic in controlling of traffic were used in addition to a feed back mechanism.

Fuzzy logic is a powerful problem-solving methodology with a vast number of applications in embedded control and information processing. Fuzzy logic provides a remarkably simple way to draw definite conclusions from vague, ambiguous or imprecise information. In a sense, fuzzy logic resembles human decision making with its ability to work from approximate data and find precise solutions.

Fuzzy logic is based on fuzzy set theory. Unlike traditional " either/or" set theory, fuzzy logic does not impose rigid classifications such as true or false, black and white, 0 or 1, etc. Membership in fuzzy sets is a continuous phenomenon, with values ranging from 0 to 1. This allows programmers to model vague and subjective concepts such as "very hot," "bright red," and "a long time".

All adaptive-fuzzy control systems have a common adverse feature, which can be a problem when comes to the practical situation of Sri Lankan roads. For instance, although there is a set pattern in the volume of traffic on our roads in the morning and in the evening on week days, during most other hours, it is unpredictable. In such situations, we cannot use adaptive-fuzzy systems directly to build efficient control systems. Thus, a simple feed back mechanism was used for the direct controlling of traffic. However, the feedback mechanisms depend totally on sensor data and a sensor failure can lead to chaos. Hence, an adaptive fuzzy system coupled to a feed back mechanism was implemented. The system can function without leading to chaos even under a failure of a sensor.

2.2 Hardware concepts

A hardware base is required for any traffic control system. It should posses the properties such as, smallness in size, low power consumption, computational abilities and suitability for outdoor use. PIC is a highly integrated subclass of a microprocessor family that can fulfill these requirements.

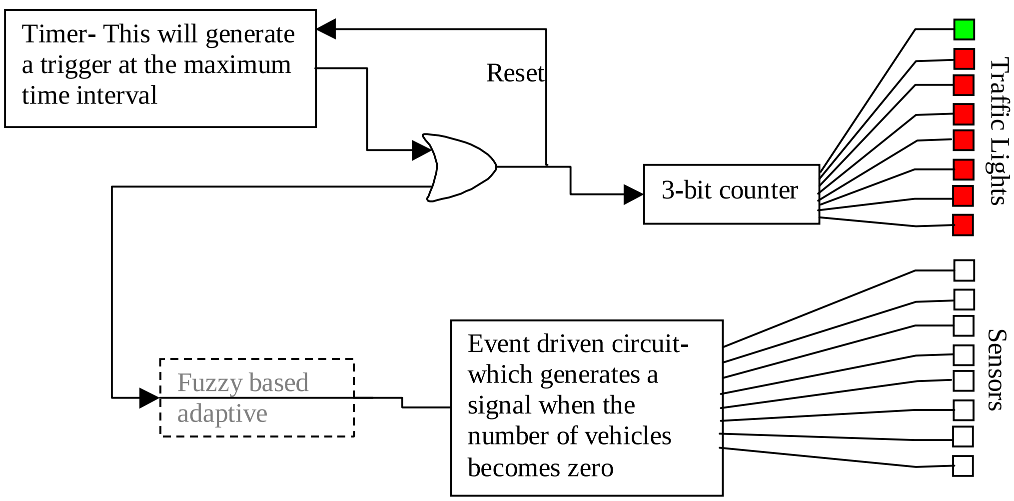
In addition, emphasis was given not to develop closed, proprietary architectures aimed at restricted sets of tasks.

3. METHODOLOGY

An OOPIC micro controller was used as the main hardware element in this project. Although the OOPIC micro controller has a very low computing power, it is very useful for outdoor use. It is very simple and inexpensive. The software can be loaded to the OOPIC micro controller easily through its serial input.

3.1 Feedback mechanism

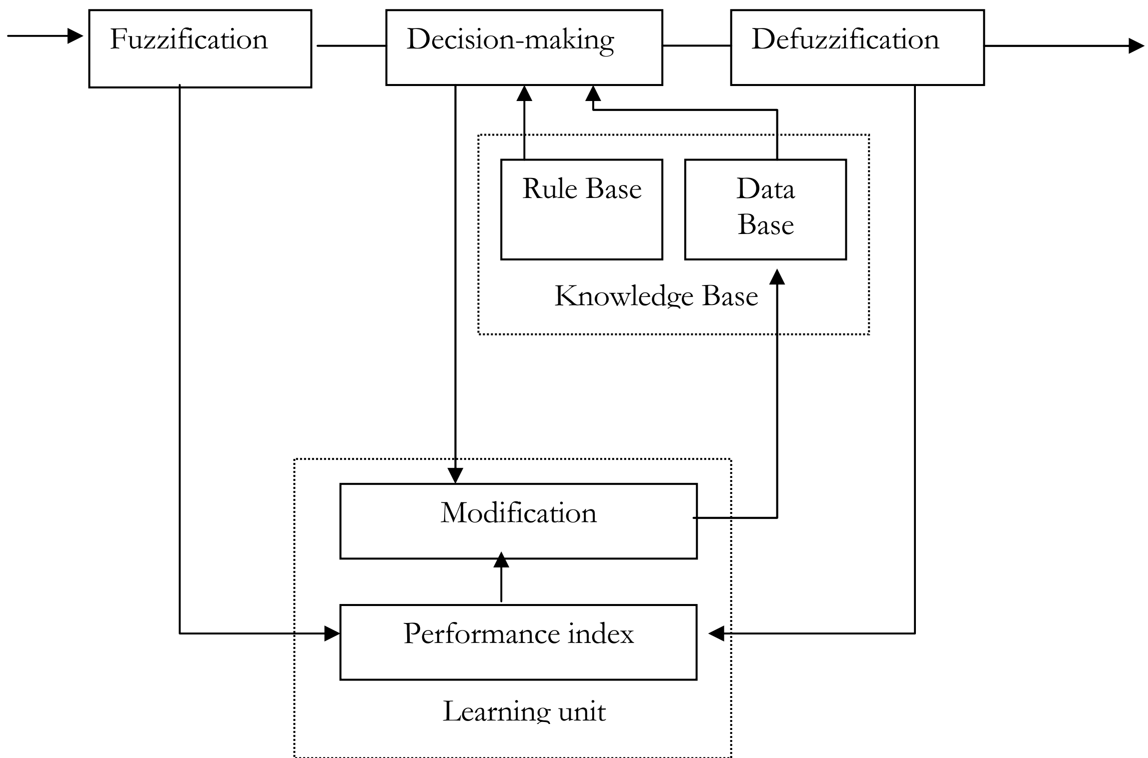
It was assumed that a set of sensors installed at the junction supply the OOPIC, particulars pertaining to vehicular traffic at any given moment of time. For the present work, the sensor data were simulated. The control software computes the number of vehicles in all lanes and the moment the number falls to zero for the lane that is given green light, the traffic signal is changed to favour the next lane. If there are vehicles in all lanes, then the timing stored in the EEPROM will be used in controlling of the traffic lights. However, the performance of this type of feedback mechanisms depends solely on information received from the sensors.



The figure given above shows the basic (simple) mechanism, which controls the traffic lights. There is an event driven mechanism with the OOPIC software, which became very useful in this project (this is an interrupt routine). The event driven circuit always check for the number of vehicles in each lane independent of the main routine. Either the event driven circuit or the timer generates a signal at the end of the maximum time interval, which trigger the counter and change the traffic sequence.

3.2 Adaptable fuzzy mechanism

A separate sub-system was developed to prevent the above feedback mechanism leading to disastrous situations, that may arise due to a sensor failure. The sub-system decides whether the decision taken by the feedback system is acceptable or not by studying the past data stored in the EEPROM.



The developed subsystem is a fuzzy–neural mix subsystem. It makes decisions based on the data it receives and the data it previously obtained to change the time allocated to each lane. The sub-system 'learns' continuously and adapt to the most acceptable time allocation for each lane on a given day at a given time.

The OOPIC microcontroller has only 32kB EEPROM as the standard to store data. However, this is not enough for this project since one needs to store timing and fuzzy levels for various dates and times. Hence another two 256kB EEPROMS were interfaced to the OOPIC. The main function of this system was handled by the two separate timing tables stored in the EEPROM; one for the timing and the other for the range of the time.

To access the data stored in the EEPROM's easily, the addresses were formatted according to the day (Sunday, Monday - Friday, Saturday and Holidays), hour and minute.

For time, one fuzzy set *(Lower Time, Same Time, and higher Time)* and for the range, another fuzzy set *(Small Range, Mid Range, Large Range)* was used. By using these two fuzzy sets, one can optimize the system to find the extreme cases (assuming no sensor malfunction).

The fuzzy sets were defined by using the previously recorded data and the timing was obtained from the feedback system. The rules were implemented using the "IF", "THEN", "ELSE" conditions at the OOPIC level.

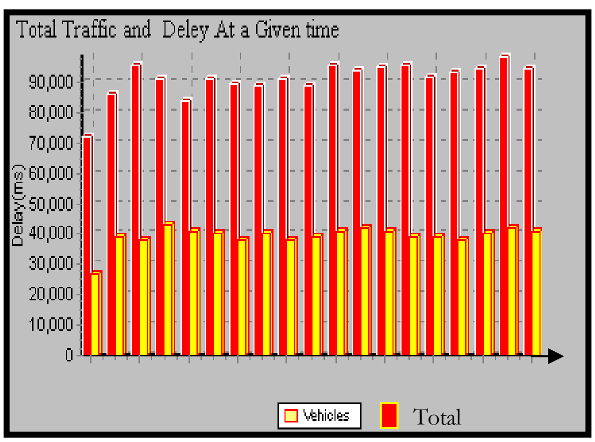
4. DATA ANALYSIS

In order to assess and analyze the efficiency of the implemented control system, a simulation was developed and the performance was compared with three systems, namely, programmed time systems, adaptive fuzzy systems and feedback based fuzzy systems subjected two conditions, adaptivity without variation and adaptivity with variation.

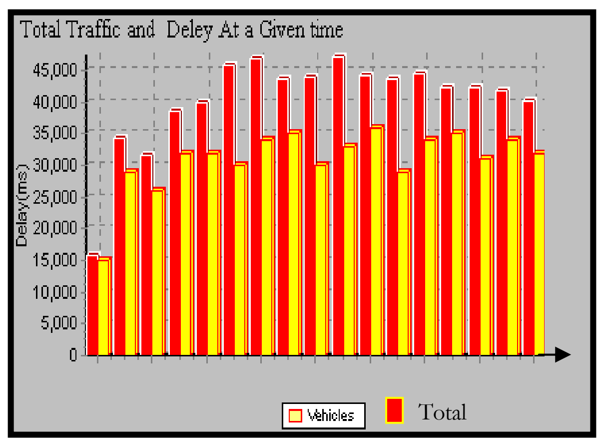
4.1 Adaptivity without variation

Here, the efficiency of each system was studied without changing the average ratio of vehicles coming on each lane. Since the simulation program generates vehicles using a normal distribution, average number of vehicles was kept as a constant.

First, the programmed time system and the total adaptive fuzzy system were compared.



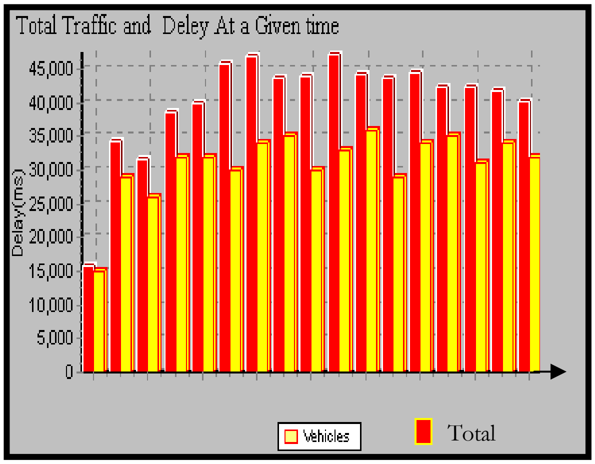
Programmed time system
(No variation in traffic)



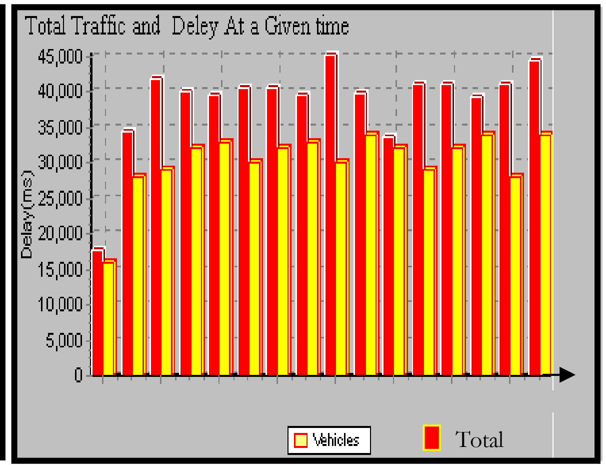
Total neuro-fuzzy system
(No variation in traffic)

The above two graphs shows that the adaptive-fuzzy system is more efficient (almost twice) compared to the programmed time system. The efficiency of the programmed time system is low (since it cannot adapt to the new situation) due to the change in the number of vehicles arriving at the junction.

Then the adaptive fuzzy system and the feedback based adaptive fuzzy system were compared.



Total neuro-fuzzy system
(No variation in traffic)

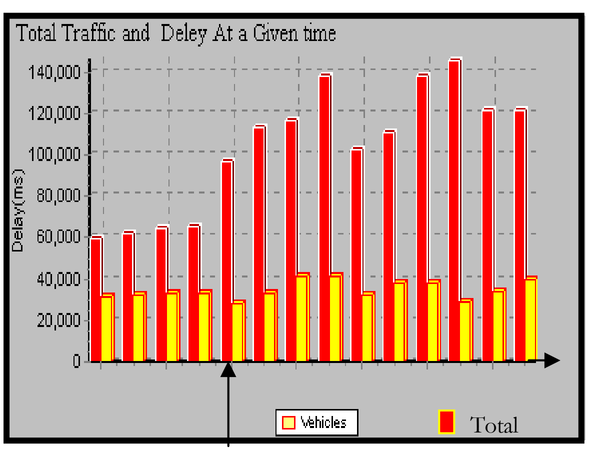


Feedback adaptive fuzzy system
No variation in traffic

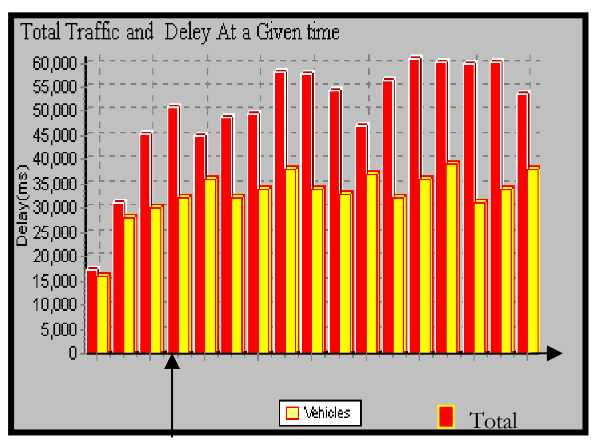
No clear difference in the efficiency of the two systems was observed. The implication is that the feedback system is unnecessary when there is no substantial variation in the traffic patterns.

4.2 Adaptivity with variation

At the outset, the same ratio of vehicles (as above) was used. After some time, the number of vehicles in one lane was changed. Then the response of the traffic light system to accommodate this change was recorded. The change was introduced in the 4^{th} round.



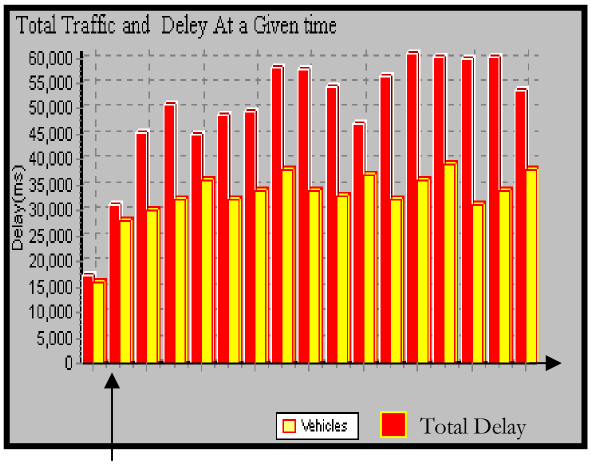
Programmed time system
(Variation was introduced in the 4^{th} round)



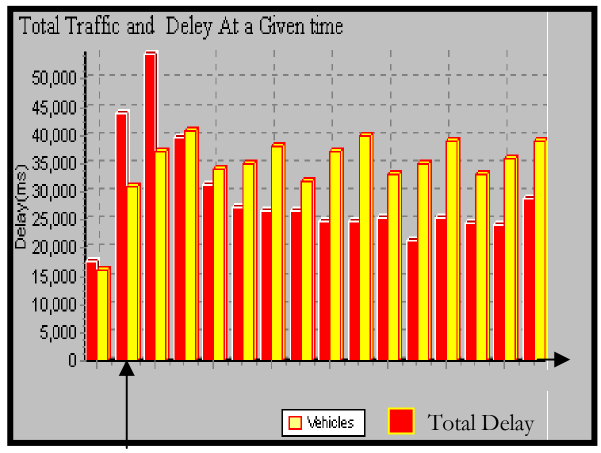
Neuro-fuzzy system
(Variation was introduced in the 4^{th} round)

As the two graphs clearly indicate, the total adaptive fuzzy system is more efficient compared to the programmed time system.

In order to compare the adaptive fuzzy system and the feedback based adaptive fuzzy system the change was introduced in the 2nd round.



Neuro-fuzzy system
(Variation was introduced in the 2nd round)



Feedback adaptive fuzzy system
(Variation was introduced in the 2nd round)

The results shown above clearly indicate that the feedback based fuzzy system is more efficient than the adaptive fuzzy system without feedback mechanism.

It can be also seen that the feedback based fuzzy system responds to the change at first but the fuzzy suspends the activation of the feedback mechanism suspecting an error. Then, being satisfied that there is no error, the feedback system adjusts the time duration accordingly.

5. CONCLUSIONS

From the work carried out under this project, we can conclude that the feedback based adaptive fuzzy traffic control system is more efficient when compared to either a system based on programmed time or adaptive fuzzy system without feedback.

The only missing items in this pilot project are the actual sensors. It has been developed in all other respects to suit all practical aspects of a complete traffic control system.

One superior feature of this system is the low cost which is well below the cost of the standard systems implemented on the local roads today.

Maintenance of the system is quite simple. A separate software package has been developed for debugging purposes. This software can be used for any PIC application. Using a laptop computer, one can obtain data pertaining to parameters and the executing software, and even implement changes to the operating software if required, while the traffic lights are working.

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