AN INTELLIGENT TRAFFIC CONTROLLER BASED ON FUZZY LOGIC

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Abstract

Traffic light plays an important role in the urban traffic management. Therefore, it is necessary to improve the traffic controller for effective traffic management and better traffic flow leading to greener environment. In this paper, an intelligent traffic light controller is proposed, utilising the fuzzy logic technology and image processing technique. A fuzzy logic control has been implemented to provide the attribute of intelligence to the system. For real-time image acquisition, the process is further linked to the fuzzy logic controller which generates a unique output for each input pattern. Here image processing and fuzzy logic tool boxes of MATLAB are used where the final output is sent to Peripheral Interface Controller (PIC) microcontroller to drive the traffic signals in the desired manner. The results obtained show an improvement of 26% in the overall outcome of traffic management as compared to the conventional traffic controller, marking great feasibility and practicality of the current model.

KEYWORDS

Image Processing, Fuzzy Logic Controller, Real-Time, Microcontroller, Intelligent, Traffic Management

INTRODUCTION

One of the prerequisites of traffic control and management involve the use of traffic signals. Their main goals are improving the traffic safety at the intersection, maximising the capacity at the intersection and minimising the delays [2.3]. On a larger scale, the effectiveness of traffic flow yields a number of economic and environmental benefits [6]. The conventional traffic controller comprises of a constant cycle for the signal operation and the output is indicated in red, yellow or green colours. A lot of advancements have been made in the traffic light control systems. Such as set-ups function according to the 'time-of-day' principle. Further research and knowledge of the applications of modern traffic controllers state that the vehicle-actuated controllers operate with an improved workability [4.5]. Here, the length of the green phase is adjusted according to the traffic flow and the decision making is carried out by the controller itself. Today, vehicle-actuated controllers are gaining more popularity as they hold a supreme capability of managing traffic flow on real-time basis [6.7].

In this project two traffic signals are set in a T-junction configuration as shown in Figure 1. Intelligence governed by the fuzzy logic controller has been linked to image processing which acts as a superior mode of data acquisition [1.5]. The final stage comprises role of a microcontroller which recognises and drives the traffic signals accordingly.

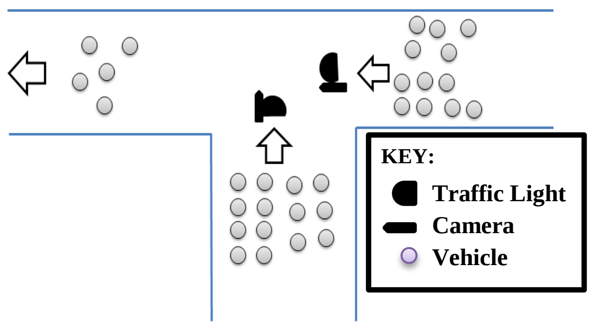


Figure 1: General Outlook of Project

IMAGE PROCESSING

The inputs regarding the number of vehicles at each participating signal are obtained through vision sensors. Coloured vision provides maximum amount of information regarding the subject which proves to be quite beneficial most of the times [1]. The same goes in the current set up in which each vehicle is detected regardless of its colour, shape and location within the work space of the vision camera.

The logic uses the background estimation for filtering each vehicle from the background along with its recognition as an independent variable. The initiation of the system is accompanied by acquisition of the base frame which is then compared with all the preceding frames. To be more precise, the base frame pixel values are compared with all the following frames. Pixel values of base frame are compared with all the following frames and difference in pixel values form the basis of vehicle recognition. Areas with different pixel values are highlighted by a rectangular frame.

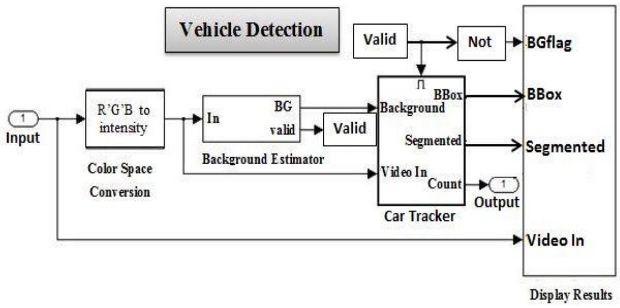


Figure 2: Overall Process of Image Processing

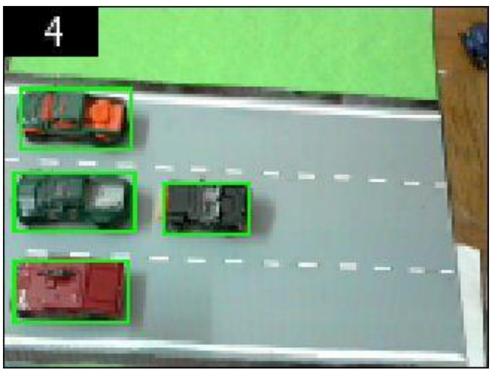


Figure 3: Sample Output Window of Processed Image from Each Vision Camera

FUZZY LOGIC CONTROLLER

The number of detected vehicles is sent to the controller which acts as the brain of the system. The capability of the system to cater inexact data and produce a unique output for each scenario forms the basis of operation. In order to maximise the depth of input acquisition, six fuzzy membership functions have been incorporated. Their relationships have been defined in the form of 'if else' statements in the fuzzy inference system. A total number of 30 rules have been defined which include all possible scenarios for each traffic signal.

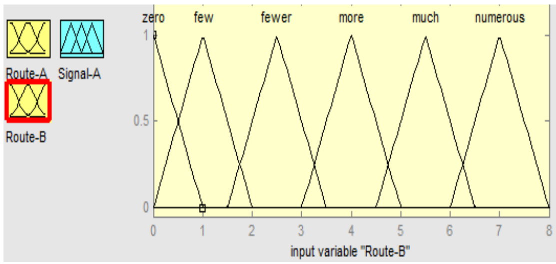


Figure 4: Input Fuzzy Membership Functions

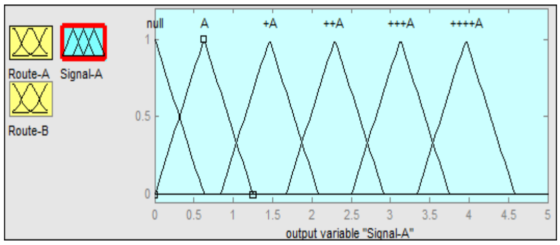


Figure 5: Output Fuzzy Membership Functions

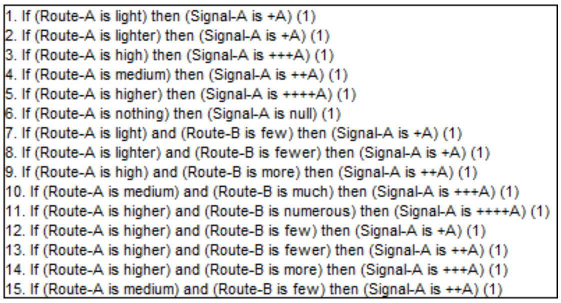
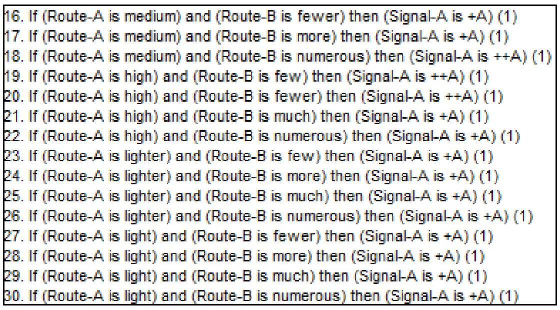

1. If (Route-A is light) then (Signal-A is +A) (1)
2. If (Route-A is lighter) then (Signal-A is +A) (1)
3. If (Route-A is high) then (Signal-A is +++A) (1)
4. If (Route-A is medium) then (Signal-A is ++A) (1)
5. If (Route-A is higher) then (Signal-A is ++++A) (1)
6. If (Route-A is nothing) then (Signal-A is null) (1)
7. If (Route-A is light) and (Route-B is few) then (Signal-A is +A) (1)
8. If (Route-A is lighter) and (Route-B is fewer) then (Signal-A is +A) (1)
9. If (Route-A is high) and (Route-B is more) then (Signal-A is ++A) (1)
10. If (Route-A is medium) and (Route-B is much) then (Signal-A is +++A) (1)
11. If (Route-A is higher) and (Route-B is numerous) then (Signal-A is ++++A) (1)
12. If (Route-A is higher) and (Route-B is few) then (Signal-A is +A) (1)
13. If (Route-A is higher) and (Route-B is fewer) then (Signal-A is ++A) (1)
14. If (Route-A is higher) and (Route-B is more) then (Signal-A is +++A) (1)
15. If (Route-A is medium) and (Route-B is few) then (Signal-A is ++A) (1)

Figure 6: Fuzzy Inference System Rules



16. If (Route-A is medium) and (Route-B is fewer) then (Signal-A is +A) (1)
17. If (Route-A is medium) and (Route-B is more) then (Signal-A is +A) (1)
18. If (Route-A is medium) and (Route-B is numerous) then (Signal-A is ++A) (1)
19. If (Route-A is high) and (Route-B is few) then (Signal-A is ++A) (1)
20. If (Route-A is high) and (Route-B is fewer) then (Signal-A is ++A) (1)
21. If (Route-A is high) and (Route-B is much) then (Signal-A is +A) (1)
22. If (Route-A is high) and (Route-B is numerous) then (Signal-A is +A) (1)
23. If (Route-A is lighter) and (Route-B is few) then (Signal-A is +A) (1)
24. If (Route-A is lighter) and (Route-B is more) then (Signal-A is +A) (1)
25. If (Route-A is lighter) and (Route-B is much) then (Signal-A is +A) (1)
26. If (Route-A is lighter) and (Route-B is numerous) then (Signal-A is +A) (1)
27. If (Route-A is light) and (Route-B is fewer) then (Signal-A is +A) (1)
28. If (Route-A is light) and (Route-B is more) then (Signal-A is +A) (1)
29. If (Route-A is light) and (Route-B is much) then (Signal-A is +A) (1)
30. If (Route-A is light) and (Route-B is numerous) then (Signal-A is +A) (1)

Figure 7: Fuzzy Inference System Rules (Cont.)

The concept of extension of signal operation time provides longer green light intervals for routes with a greater amount of traffic. The testing and functioning of the system has been carried out on a scaled down version of the whole set up, therefore, overall number of the vehicles has been kept to minimum.

S/No.	Number of Vehicles	Output Time (s)
1	1-3	5
2	4-5	10
3	6	15
4	7	20

Table 1: Projected Resultant Output Time according to Different Inputs

PIC16F877A MICROCONTROLLER

The fuzzy logic controller is then followed by the PIC 16F877A microcontroller which manages the traffic lights according to the data it receives from the controller. The main role of the microcontroller is to serially receive and manipulate the data from the controller and carry out particular actions. For instance, when the input to the microcontroller denotes that there are six vehicles, the output from the microcontroller is 15 seconds. Moreover, the microcontroller also ensures that the green light of the traffic signals operates in alternate manner. Real-time functioning of the set up takes into account the traffic conditions only when the microcontroller is held at its default state which is during no operation of any signal. The logic used in programming of the microcontroller and the overall set up has been given in Figure 8 and Figure 9.

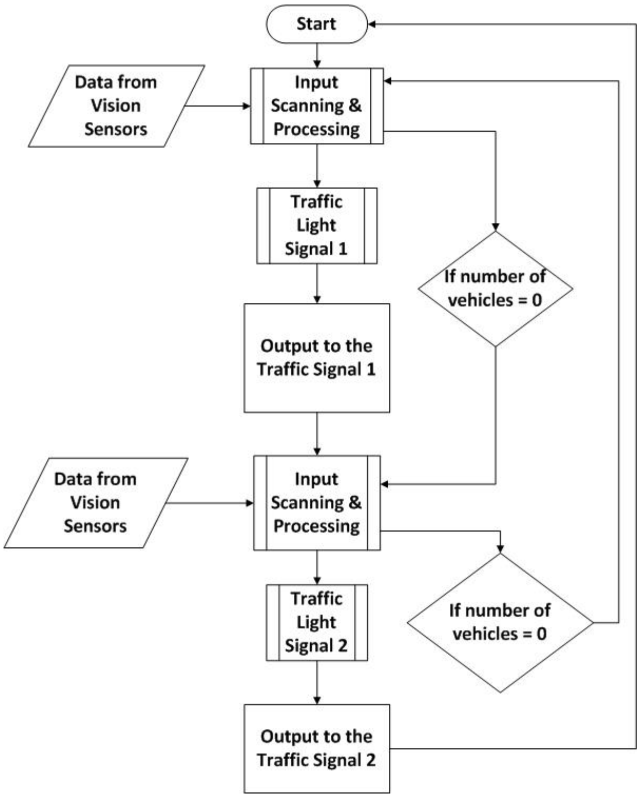


Figure 8: Flowchart of Overall System Working

Figure 9 shows the overall logic used for the whole system where two main stages of Simulink and microcontroller are involved.

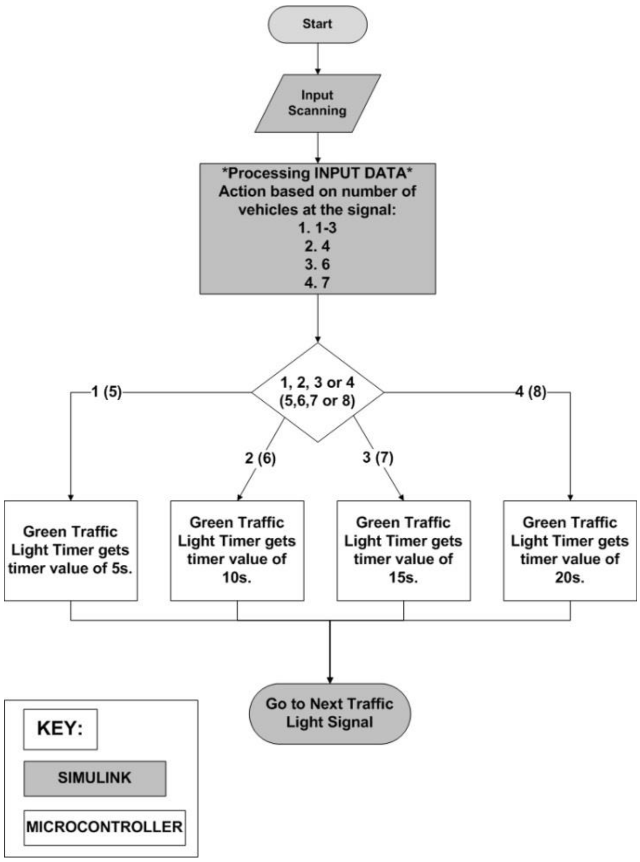


Figure 9: Traffic Signal Operation

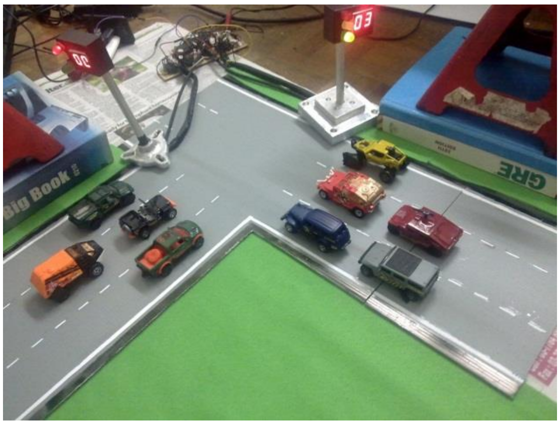


Figure 10: Prototype Testing

RESULTS AND DISCUSSION

The results are obtained from a specially made prototype shown in Figure 10. And they are compared to that of standard versions of traffic light operations. Such basic systems usually have pre-defined timing values. Here the results show that there is an improvement of approximately 26% in overall performance as compared to the conventional traffic controller as shown in Table 2. This is based on a T-junction which includes only a single pair of traffic signals.

The fuzzy inference system algorithm also offers the flexibility of prioritising particular routes where the preference is given to the traffic on main route in relation to other participating routes.

Signal A No. of cars	Signal B No. of cars	Signal A Single operation time CTC (s)	Signal B Single operation time CTC (s)	Signal A Single operation time IFLTC (s)	Signal B Single operation time IFLTC (s)	Conventional Traffic Controller (CTC) (s)	Intelligent Fuzzy Logic based Traffic Controller (IFLTC) (s)
5	2	15	15	15	5	30	20
2	7	15	15	5	20	30	25
6	6	15	15	15	15	30	30
7	0	15	15	20	0	30	20
3	6	15	15	5	15	30	20
5	7	15	15	10	20	30	30
2	2	15	15	5	5	30	10
Total No. of cars	**Total No. of cars**	**Total Time (s)**	**Total Time (s)**	**Total Time (s)**	**Total Time (s)**	**Total Time (s)**	**Total Time (s)**
30	**30**	**105**	**105**	**75**	**80**	**210**	**155**

Table 2: Results of Comparison between Conventional Traffic Controller and Intelligent Fuzzy Logic based Traffic Controller

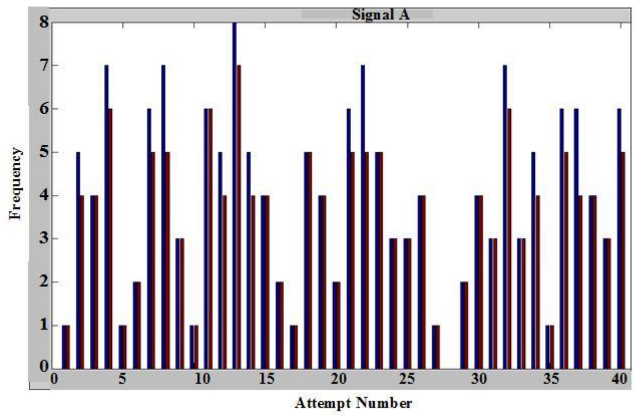


Figure 11: Output Trends between Practical and Expected Values for Signal A

The comparison of each route has also been tested separately and the time taken in each cycle to manage a given random number of vehicles by each traffic signal is represented in form of bar charts as shown in Figure 11 and Figure 12.

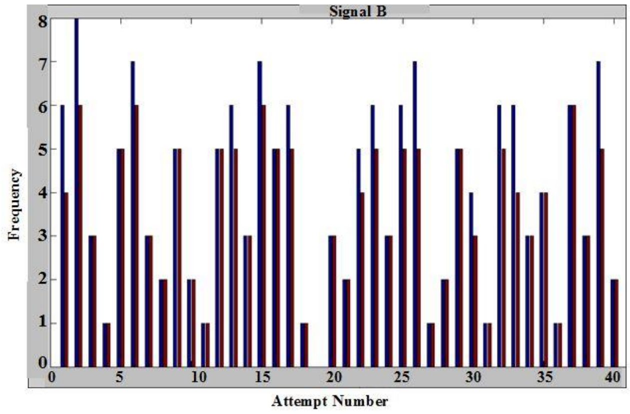


Figure 12: Output Trends between Practical and Expected Values for Signal B

CONCLUSION

In conclusion, this paper has successfully demonstrated an improved traffic controller using fuzzy logic, image processing techniques and microcontroller.

For future work, the system can also be linked to a database to keep track of the traffic information which is beneficial for security purposes, pedestrian traffic management and air traffic control.

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