International Journal of Emerging Trends & Technology in Computer Science (IJETTCS)
Web Site: www.ijettcs.org Email: editor@ijettcs.org, editorijettcs@gmail.com
Volume 2, Issue 6, November – December 2013 ISSN 2278-6856

Intelligent System for Automated Traffic Signal Control Using Fuzzy Mamdani Model

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Abstract: ***The work describes a flexible traffic control technique employing the Fuzzy Logic based Mamdani Controller. The control technique makes adjustments in the on and off timings of various lanes at a traffic junction depending on the actual condition of traffic, unlike the traditional microcontroller based approach which keeps time slots fixed regardless of actual situation. The parameters like traffic density and queue length have to be obtained by applying image processing algorithms for clustering, segmentation, and partitioning to the aerial images of the traffic situation at the junction or crossing. On the basis of the traffic density conditions on the presently green lane and that in the next two waiting lanes, the time duration for the presently green lane can be dynamically adjusted in real time to adapt to the situation at the traffic island. The decisions about the adjustment in time may be taken on the real time parameters using fuzzy inference engine.***

Keywords: Fuzzy controller, Visual Feedback, Traffic controller, Real Time application

1. INTRODUCTION

The world we live in today is a world of automation. Most things around us, manufactured for human use or service, are controlled using microcontrollers. Traffic signal control is a well-known application of microcontroller based automation, which is a part of most of the basic courses on microprocessors and microcontrollers. Unfortunately, the traditional control system is not flexible but fixed. The real time situation of the junction is not taken into consideration. Rather, the on and off timings of the green, red and amber lights are prefixed to some optimal values from previous planning and experience, and programmed into the system forever. At best, these durations may be varied as per the time of the day or the day of the week (weekday or weekend etc.). There is no scope for real time adjustment of the durations in accordance with the actual traffic condition at the crossing. Artificial systems which use human like decision processes to arrive at decisions come to the rescue. [3]. This paper discusses an approach for introducing such aforesaid flexibility into the system.

For this work, the traffic situation is to be entered by an operator through a graphical user interface. The program asks the user to enter the value indicating the traffic situation and takes the decision. *But in actual applications,* there will be no human operator entering any values. The system will take input parameters from image processing of images continuously obtained at the traffic junction. [2], [6]

2. THE PRESENT DAY APPROACH

The system in common use today is being discussed assuming a Left Hand Drive system with free left turn, as in use in India. The discussion is with reference to Fig. 1.

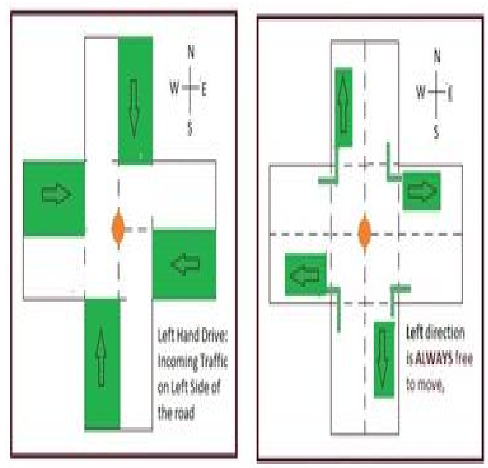


Figure 1 The Traffic Junction In A Left Hand Drive System. (A)Vehicles Arrive On The Left Hand Side Of The Road On All Four Sides.(B) Vehicles Are Always Free To Turn Left.

In the usual scenario, a microcontroller controls the four sets of traffic lights at the crossing (traffic island). Typically, the green light is turned on in one direction and red in the other three, and the same thing is repeated in each direction turn by turn, as depicted in Fig. 2.

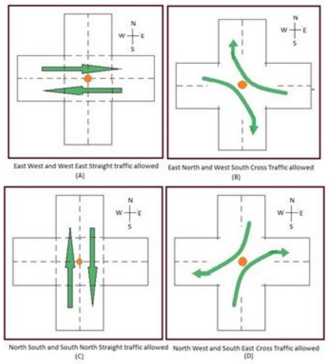


Figure 2.The Four Controlled Situations At A Quad Traffic Island

(A) Traffic Allowed To Move In East West And Also West East (Straight) Directions

(B) Traffic Allowed To Move In East North And Also West South (Right Hand Side) Directions

(C) Traffic Allowed To Move In North South And Also South North (Straight) Directions

(D) Traffic Allowed To Move In North West And Also South East (Right Hand Side) Directions

The durations for the "ON" timing are usually fixed, and same, for all the four directions. These days the timings in seconds are displayed towards the respective directions so that people know exactly how much they have to wait / cross, before the current situation changes. The ordering is made such that two directions which do not cross each other are allowed to move at any given time and the others are made to wait.

We have all come across situations in which we can see that there is no (or very less) traffic moving on the presently permitted lane while we still have a long waiting period. This situation is not only irritating to the commuters, but also instigates drivers in a hurry to break the rules and jump the signal – a situation which may lead to accidents, and very often does lead to such.

3. THE PROPOSED APPROACH

The technique in use today, which has been described above, is nonflexible.At the very least, it causes discomfort and anxiety to commuters waiting for a green light while they can visually see for themselves that there is no traffic in the presently "ON" lane. Further, if it becomes a daily routine which one faces when in a hurry to reach office or picking up the kids, then it leads to a habit of ignoring the red signal, thereby causing accidents in the long run.

As we move towards automation of traffic junctions we have to take care that the automated lights have to be made to accommodate the actual traffic demands and requirements, like the human counterpart used to do, and not be just there as name sake regulators. In the good old non-automated days, there used to be policemen at traffic crossings, and they could visually see the traffic density in different lanes and adjust the timings as per the need of the hour, while also maintaining fairness; i.e. the lane with low traffic was also given a fair share of time, though not so much as to be wasteful. In contrast to this the typical automated system has no such capacity. This paper discusses a fuzzy logic based approach which simulates the human approach to solve this problem. The heuristic and implementation are discussed here.

3.1 The Heuristic:

- Turn On the green light towards all left turns.
- Turn on the green light in East West and West East non interfering directions and red light in all other directions.
- Wait for an interval T which is adjustable within specified maximum and minimum time limits. The amount of variation is "T_{adjust}"which depends on the condition of traffic.
- Repeat the above two steps for the three other direction pairs cyclically.
- Repeat the whole cycle continuously unless forced to quit the loop.

3.2 The Implementation:

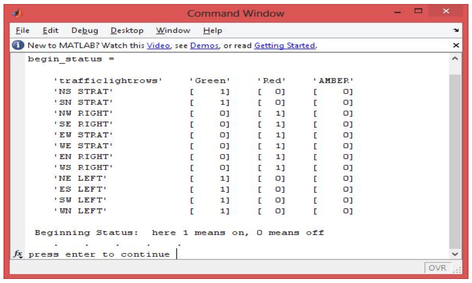
The above heuristic was implemented in Matlab using Fuzzy Logic Toolbox and the MamdaniController [1], [4].The algorithm is described below.

- Set the values of T_{min}, T_{max}, T_{left}, and $T_{elapsed}$; viz. the minimum time interval, the maximumtime interval, the time left for the current situation to continue before it changes, and the time elapsed from the beginning of the present cycle.
- For each pair of directions, turn on the green lights (red for other directions) for a minimum time, set the timer, wait for a minimum interval, and check for traffic densities in the open and waiting lanes.
- Ask the user for the traffic densities in respective lanes. In real situations this value will be taken from image processing. But for this simulation, values have to be entered by the user executing the program through the Graphical User Interface.
- The rules are as follows:

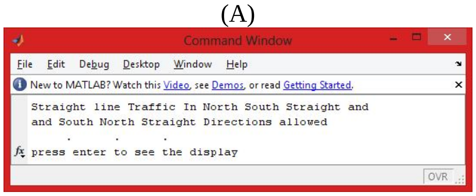
o R1: Crisp Rule:
If (Time elapsed in allowed lane >= Minimum On time)
Then {Apply Rule 2}
Else {Wait for 1 minute and reapply Rule 1}

o R2:
If (Traffic in the allowed lane is >Minimum threshold value)
Then {Continue the time slot without any reduction)
Else {Apply Fuzzy Inference Engine (FIS) to find adjustment in time}

- FIS: The Fuzzy Inference Engine: The fuzzy engine was made using 27 rules based on three input antecedents (the traffic in the presently open lane, and the traffic in the next two waiting lanes) and one fuzzy consequent (the adjustment in time which may be done). Figures below show snapshots from the Matlab implementation



(A)



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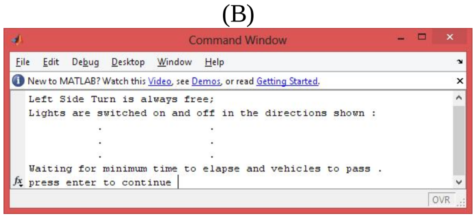

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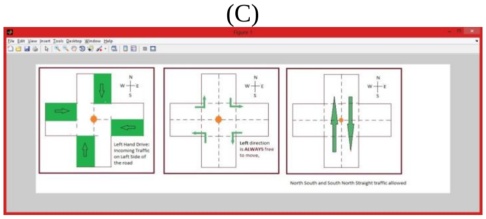
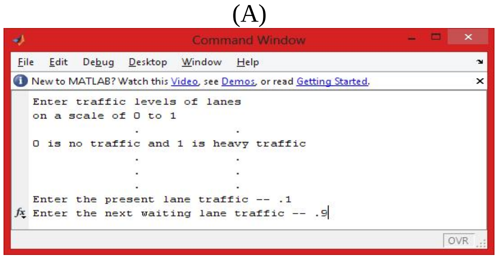


(D)

Figure3(A), (B), (C) The GUI Showing The Present Status Of The Junction, And (D) The Traffic Directions Graphically

(A)

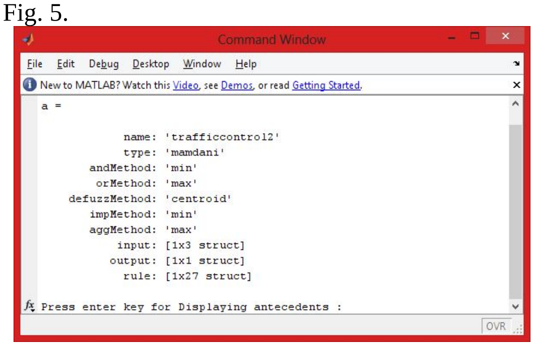


(B)

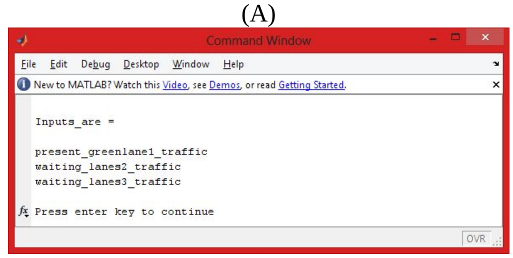
Figure 4(A) The GUI Showing The Traffic Situation

(B) The GUI Asking To Enter The Traffic Density Values. In Actual Implementation These Will Come From The Image Processing System.

The FIS description, antecedent and consequent membership curves are shown in the snapshot of the FIS. in Fig. 5.



(A)



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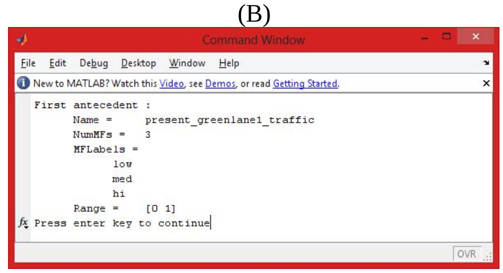
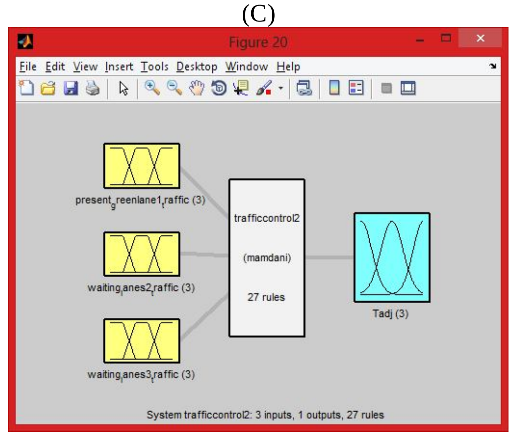


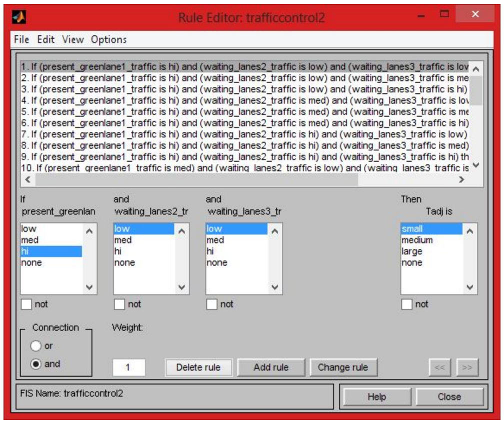
(C)



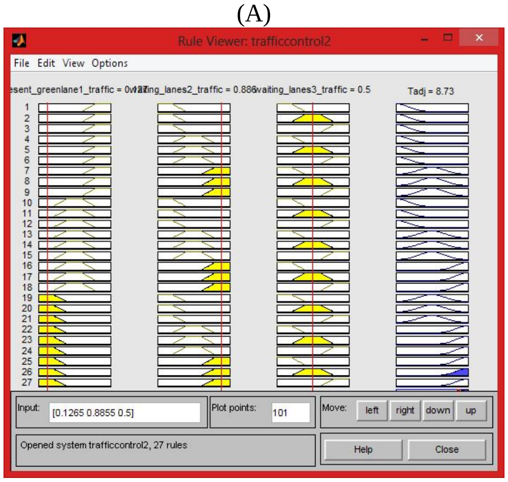
(D)

Figure 5(A)The Fuzzy Inference Engine (B) The Inputs (C) The Description Of One Antecedent (D) Graphical Representation Of The FIS.

Fig. 6 shows the Rule view and the Application view. Fig. 7 shows the surface view and Fig. 8 depicts the next cycle of the implementation.



(A)



(B)

Figure 6 (A) The Rule-View
(B) The Application View
Of The FIS Execution.

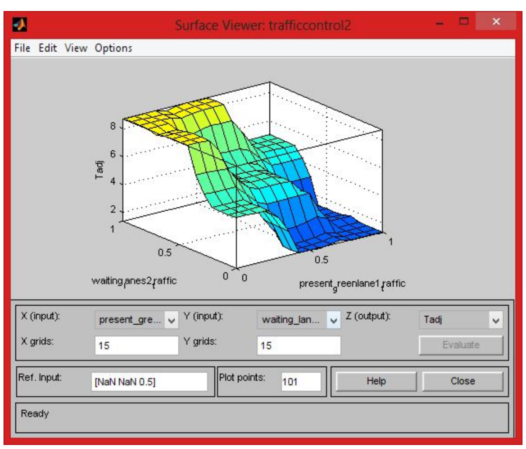
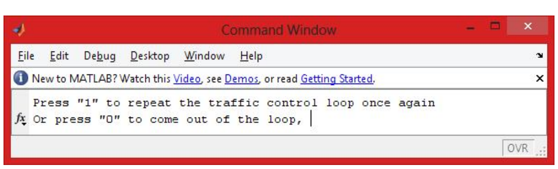
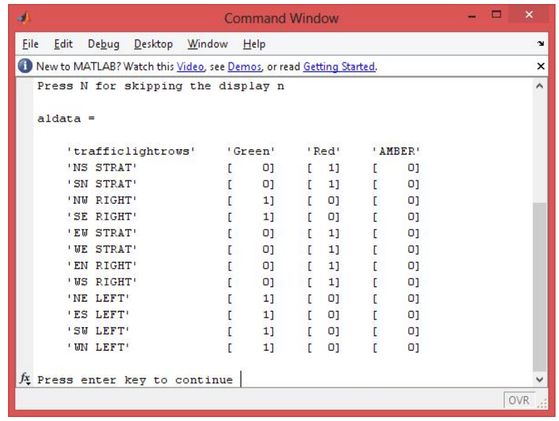


Figure7 The Surface View Of The Fuzzy Inference.



(A)



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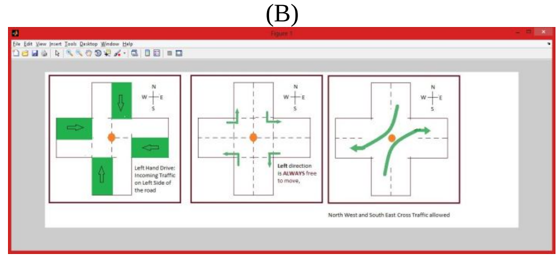

(C)

Figure 8(A) TheGUI Asking The User Whether To Run The Next Cycle Or Quit
(B) The Situation In The Next Cycle.
(C) The Graphical Display Of The Next Cycle Of The Implementation

3.3 Acquiring Feedback variables:

Cameras can be placed to have a bird's eye view of the junction or even the individual incoming traffic lanes. The acquired image may be subjected to image processing methods [5] to find the densities of traffic in real time. There would be no necessity of a human operator to enter the values of traffic densities manually.

3.4 FIS Model Description:

The Fuzzy Inference method described in this paper was based on the Mamdani Model. The antecedent membership curves have been selected trapezoidal while the consequents are Gaussian. The "And" operator was taken as 'min', and "Or" as 'max'. Implication function was 'min', while aggregation function was 'max'. Finally, defuzzification was found using centroid approach.

4. CONCLUSION AND FUTURE SCOPE:

he Fuzzy Logic Based Control System developed here for traffic signal control is very flexible. The timings of adjustment, the minimum and maximum time limits can easily be altered to suit various junctions, while the structure of the rule set can be kept fixed. Even the rule-set may be varied to cater to the needs of different scenarios. The definitions of the fuzzy sets of the antecedents are also very easily changeable.

The feedback for the traffic densities or / and queue lengths can be taken from images from cameras above. Image processing techniques can be simply applied to the images of separate the areas of interest, i.e. the concerned lanes. The images can be analyzed to find the attributes; viz. the length of the queues or the traffic density. Presently, this proposed method has been simulated with satisfactory results. This is a very promising application of fuzzy logic in practical areas, and will be quite useful in traffic control at automated unmanned crossings which are common in the high-speed world today.

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AUTHORS BIOGRAPHY

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