Traffic Light Control System Using Fuzzy Logic

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Abstract

This paper proposes a fuzzy logic control system that can produce almost continuous output values suitable for interactive and real-time processing. This system utilizes the fuzzy logic to control the traffic light. There are one main road and one side street at a certain traffic junction. This paper aims to develop a computer simulated fuzzy controller system that would automatically generate the durations of the green light to be lit for both ways as fuzzy output giving the main road higher priority. The numbers of arrival cars from each two ways become inputs for the fuzzy logic control system; those are the fuzzy values, of the corresponding fuzzy sets in the input membership functions. Depending on the constructed rule base together with fuzzy associative memories (FAM tables), the fuzzy output for the durations of traffic light is obtained. The weighted average defuzzification method is used in the defuzzification of the system

1.Introduction

Vehicular travel is increasing throughout the world, particularly in city areas. Therefore the need arises for simulating of fuzzy traffic control algorithms to better accommodate this increasing demand. In this paper, the programming of Matlab for conventional traffic light controller at intersection and the simulation of fuzzy traffic light controller that is adaptive to the vehicle traffic density are presented.

Fuzzy logic is also called misty sets or diffuse sets, and it is an extension of the classic logic. This new methodology is one of the more recent specialties of the artificial intelligence area that aims to generate techniques to solve problems in several knowledge areas, approaching the computational decision to the human decision. Fuzzy logic uses approximate instead of exact information, imitating the human thinking [1] [3].

Nowadays fuzzy logic is used in control systems and in decision support systems where the problem description approach can not be precise. A fuzzy system is formed of output and input variables. For each variable, fuzzy sets that characterize those variables are formulated, and for each fuzzy set a membership function is built. After that, the rules that relate the output and input variables to their respective fuzzy sets are defined. The computational evaluation of a fuzzy system is formed of fuzzification (construction of output variables that define the study), inference (fuzzy reasoning application on fuzzy output) and defuzzification (translation of linguistic value to numerical value) [2] [5].

Basically, there are certain difficulties in modeling and simulating complex real-world systems for control systems development. Fuzzy control provides a formal methodology for representing, manipulating, and implementing a human's heuristic knowledge about how to control a system. This paper tries to develop a fuzzy logic system to control the traffic light [4].

The next section, Section (2), highlights the related works with the proposed system. In Section (3), background theory is discussed with step by step approach together with visual aids. The experimental result is in Section (4). The conclusions and further extensions of the system is state in Section (5).

2. Related Work

K Almejalli, K Dahal, and A Hossain,Member IEEE, have developed Road Traffic Decision Support System.LI Guo-houng , SHI Peng-Fei have written Fuzzy Logic.Kwang H.Lee, have written First Course on Fuzzy Theory and Applications . Rainer Hampel, Michael Wagenknecht,Nasredin Chaker (Eds.) also discovered Fuzzy controls in year 2000. T. J. Ross, modified Fuzzy Logic with Engineering Applications.William Siler and James J. Bukcley, wrote latest theory of Fuzzy Expert Systems and Fuzzy Reasoning.

3. Background Theory

The fuzzy controller as an artificial decision maker operates in a system in real time. Fuzzy controller is composed of the following four elements:

1. A rule-base (a set of If-Then rules) holds the knowledge, in the form of a set of rules, of how best to control the system.

2. The inference mechanism evaluates which control rules are relevant at the current time and then decides what the input to the plant should be.
3. The fuzzification interface simply modifies the inputs so that they can be interpreted and compared to the rules in the rule-base.
4.The defuzzification interface converts the conclusions reached by the inference mechanism into the inputs to the plant [4].

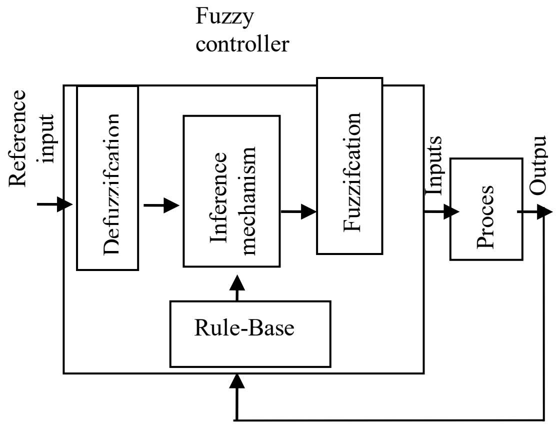


Figure1. Fuzzy control system design

4. Experimental Results

The number of vehicles on main road as well as on the side street has to be fuzzified. Then the durations of the traffic light are calculated out from these two fuzzificated values. Actually, the outputs, durations of the traffic light are according to the fuzzy output. All the necessary design calculations are stated in this chapter. All the possible combinations of different inputs are also summarized.

To construct the membership functions for the number of vehicles on the main road and side street, the numbers of vehicles are partitioned into five membership functions, Very Small (VS), Small (S), Medium (M) and Large (L), Very Large (VL). The VS membership function defines number of vehicles on main road 0 has fuzzy value ‘1’, the S membership function defines number of vehicles on main road 15 which has fuzzy value ‘1’, the M membership function defines number of vehicles on main road 30 which has fuzzy value ‘1’, the L membership function defines number of vehicles on main road 45 which has fuzzy value ‘1’, the VL membership function defines number of vehicles on main road 60 which has fuzzy value ‘1’.

The membership functions for the number of vehicles on the main road and side street are graphically represented in Figure 2 and 3. In this graph, the x-axis represents the number of vehicles on the main road and side street, and the y-axis represents the corresponding fuzzy values according to the relative membership functions.

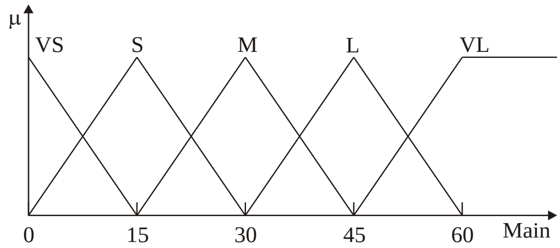


Figure2. The membership function for the number of vehicles on main road

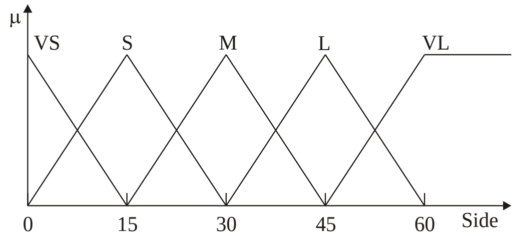


Figure 3. The membership function for the number of vehicles on side street

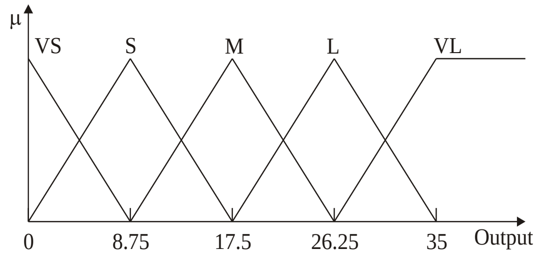


Figure 4. The membership function for output duration

To construct the membership functions for output duration on both of the main road and the side street, the output duration are partitioned into five membership functions, Very Small (VS), Small (S), Medium (M) and Large (L), Very Large (VL). The VS membership function defines output duration 0 which has fuzzy value ‘1’, the S membership function defines output duration 8.75 which has fuzzy value ‘1’, the M membership function defines output duration 17.5 which has fuzzy value ‘1’, the L membership function defines output duration 26.25 which has fuzzy value ‘1’, the VL membership function defines output duration 35 which has fuzzy value ‘1’.

The membership functions for the output duration are graphically represented in Figure 3. In this graph, the x-axis represents output duration on the main road and the y-axis represents the corresponding fuzzy values according to the relative membership functions.

The fuzzy logic of the system contains two fuzzy inputs (number of vehicles on both main road and side street) and one fuzzy output (output duration of traffic light). The two fuzzy inputs (number of vehicles on both main road and Side Street) are partitioned into five membership functions and the fuzzy output is partitioned into five membership functions. To fit for this situation, the fuzzy associative memories (FAM) table is designed as in Table 1. The membership functions of the number of vehicles on both main road and side street are taken as input of the FAM table and the output of the FAM table is partitioned into five regions; Very Small (VS), Small (S), Medium (M), Large (L), Very Large (VL).

Table 1. Fuzzy associative memories (FAM) table of the system

S \ M	VS	S	M	L	VL
VS	VS	S	M	M	M
S	S	M	M	L	L
M	M	M	L	L	VL
L	L	L	VL	VL	VL
VL	VL	VL	VL	VL	VL

The next step was building the rule-based structure. This was done by breaking the control problem down into a series of IF X AND Y THEN Z rules that define the desired system output response for given system input conditions. IF-THEN rules were used to build the rule-based structure for the proposed traffic fuzzy system, all these rules were derived from the experienced traffic decision makers. Show a selection of these rules [6].

If Main =Large and Side =Very Small then Output =Medium
If Main = Large and Side = Small then Output=Large
If Main =Very Large and Side =Very Small then Output =Medium
If Main =Very Large and Side = Small then Output = Large

Example
Initial Main = 52
Initial Side = 10

Main fires L at (0.466) and VL at (0.534)
Side fires VS at (0.334) and S at (0.666)

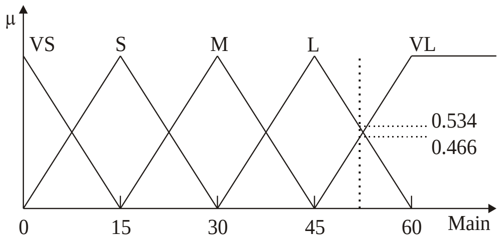


Figure 5. Positioning on main road membership functions

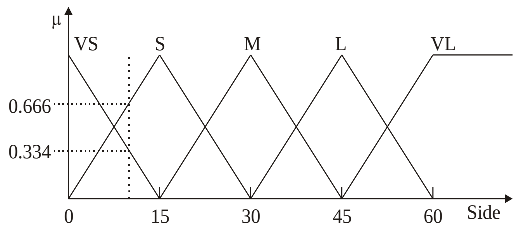
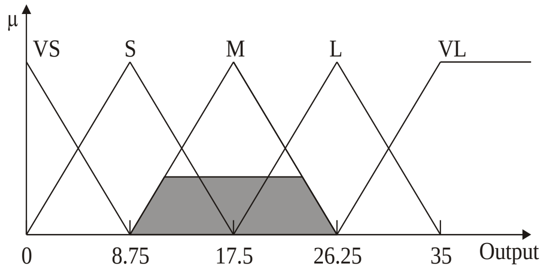
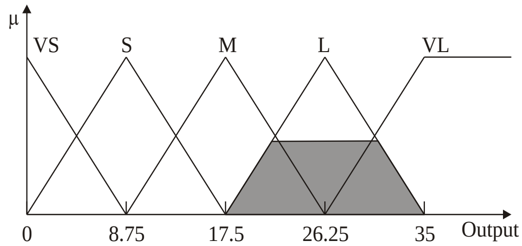


Figure 6. Positioning on side street membership functions

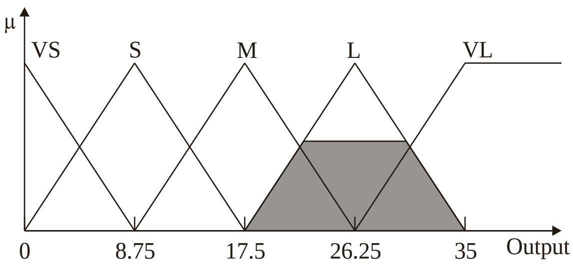
According to the FAM table, the fuzzy values must be plotted on the output membership function.



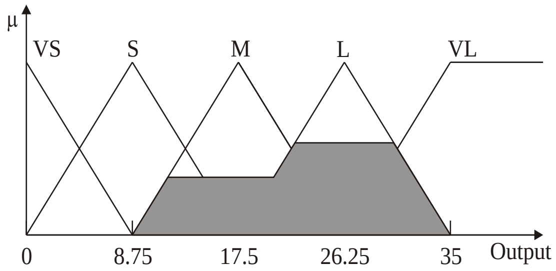
(a) Truncated value of medium membership function



(b) Truncated value of left membership function



(c)Truncated value of left



(d) Union of the Truncated Values

Figure 7. Truncated consequents and union of fuzzy consequent

By Weight Average method;[5]

$$z^* = \frac{\sum \mu_{\underset{\sim}{C}}(\bar{z}).\bar{z}}{\sum \mu_{\underset{\sim}{C}}(\bar{z})} \qquad (1)$$

z* = Output

$$\text{Output} = \frac{(0.334*17.5)+(0.446*26.25)+(0.534*26.25)}{0.334+0.446+0.534}$$

$$\text{Output} = \frac{5.845+11.7075+14.0175}{1.314} = \frac{31.57}{1.314} = 24.025\text{s}$$

5. Conclusion and Further Extension

Making the correct decision at the right time has major problem in road traffic managements, because decision-makers need to analyze and absorb a large quantity of information in a short time. This paper presented a fuzzy based decision support system to assist road traffic management. All parameters of the problem that was required to build the system have been defined and modeled using fuzzy sets. The traffic rules for the fuzzy inference system were extracted from traffic experts and historical data. In order to test and evaluate the proposed system, it has been demonstrated for a case study Traffic.

The proposed system has shown that Fuzzy logic based approach has a considerable potential to be used in the development of a road traffic management system to support decision-takers. Currently, we have demonstrated the technical feasibility of the system with the limited influencing variables/ factors which directly affect traffic decisions. In the next stage, all factors that may influence the traffic decision-making process such as road safety, drivers' behaviors, etc., should be taken into consideration. Moreover, the proposed fuzzy model can be developed to assist traffic management to improve the real time decision support systems by using historical data about the traffic problems and the control scenarios used to solve these problems. By using such information it is possible to evaluate and improve the real time traffic management systems and generate effective long term policies such as extending the road network, adding lanes, creating alternative new freeway connection, and create new traffic controls.

There are certain limitations of the system and additional extensions to update and enhance the system. Further extending to avoid the limitations of the system makes the system more sophisticated.

There are only five membership functions for the number of vehicles on the main road, side street and output duration, Very Small (VS), Small (S), Medium (M) and Large (L), Very Large (VL). These are limited number of input membership functions and output membership function.

The number of input membership functions as well as output membership functions should be added as the further extensions of the system to get more detail fuzzy output result.

Other artificial intelligence decision making techniques, such as, Artificial Neural Network (ANN) as well as Genetic Algorithm (GA) should also be applied for future analysis.

REFERENCES

[1] Kwang H.Lee, *First Course on Fuzzy Theory and Applications,* 2005. ISBN 3-540-22988-4

[2] K Almejalli , K Dahal, and A Hossain,member IEEE, *Road Traffic Decision Support System* , K.A.Al.mejalli; K.P.dahal; M.A.Hossain1 {@Bradford.ac.uk}

[3] LI Guo-houng, SHI Peng-Fei, *Fuzzy Logic*, Lgh0929@sjtu.edu.cn

[4] Rainer Hampel, Michael Wagenknecht, Nasredin Chaker (Eds.), *Fuzzy Control*, 2000. ISBN 3-7908- 1327-3

[5] T. J. Ross, *Fuzzy Logic with Engineering Applications: Instructor's Manual:* McGraw-Hill Education- Europe - Release date, 1995.

[6] William Siler and James J. Bukcley, *Fuzzy Expert Systems and Fuzzy Reasoning*, ISBN 0-471-38859-9 2005.