Traffic Control System Using Fuzzy Logic Control with Emergency Override Feature

Group - 14
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1 Introduction

This report presents a study where we see the industrial application of Fuzzy Logic in a traffic control system that has an emergency override feature as described by (Goyal 2018) [1].

City traffic monitoring and control has become a global issue due to the rising number of vehicles on the road, therefore we need ways and means to tackle this global problem. Fuzzy Logic technology enables practical rules to be applied in a manner similar to human reasoning. For instance, if humans were regulating the traffic situation then they would behave in the following way, if the traffic is high on north-south lanes and less on west-east lanes, then keep the green light longer on north-south lanes. The benefit of Fuzzy Controller is that it helps the machine to measure and comprehend ambiguous terms and conditions such as "high," "less," and "longer".

In this study, we prioritize higher amount of time for green light where there are long queues. This helps in resolving vehicular congestion quickly and makes sure that an optimum amount of time is given to each lane to clear traffic depending on the situation.

2 Description

2.1 Design

The design proposed by Goyal et. al [1] takes a 4-way intersection and involves two electromagnetic sensors, one placed on the traffic light and one a distance *D* behind the traffic light placed at each traffic light (Fig.1). While the first sensor captures the number of vehicles passing the traffic light, the second sensor captures the number of vehicles arriving at the intersection. The information from these two sensors is used to derive the number of cars arriving through any particular lane. The information about the number of cars from the different lanes is fed to the fuzzy logic controller which is in turn, connected to the traffic light controller.

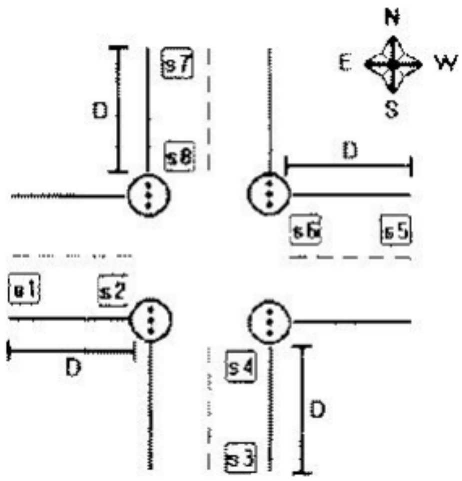


Figure 1: Arrangement of sensors around traffic lights

2.2 Assumptions

For incorporating a fuzzy logic system in this application, the following assumptions were made by the authors of the review paper:

1. The intersection is a four-way intersection with movement originating from the north, west, south and east directions.
2. When the traffic from the west and east moves then the traffic coming from the north and south side must stop, and vice-versa.
3. The fuzzy logic controller will observe the vehicle density of all four sides separately.
4. The minimum and maximum duration of the green signal is 0 and 30 seconds respectively.3 Fuzzification, Composition & De-fuzzification

3.1 Fuzzification

The first step authors of (Goyal 2018) did was to convert the input variable into appropriate fuzzy variables. They used the process of fuzzification in a nonlinear system to establish a membership degree for fuzzy partitions of different variables [1].

A fuzzy set is defined as the membership function $\mu_A(x)$, which describes the degree to which the element belongs to x and A:

$$\mu_A(x) : U \mapsto [0, 1]$$

The authors define two Input variables, namely *Arrival* and *Queue* that represent the amount of cars moving across the intersection and the amount of cars waiting at the intersection, respectively. The output variable is the Green signal *Extension Time*, defined as the amount of time to extend the green light by. The variables, their short-hands and the meanings have been defined in Table 1.

System	**Variable Name**	**Variable**	**Meaning**
Input 1	Arrival	SA NQ N E	Scarcely Any Not Quite Numerous Enormous
Input 2	Queue	S M MO L	Slight Minor Moderate Large
Output	Extension Time	Zero Short Medium Longer	Zero Short Medium Longer

Table 1: Linguistic Variables

These linguistic variables are then used for composition and inference.
The membership functions of the two variables, *Arrival* and *Queue* proposed by the authors of (Goyal 2018) are plotted below.

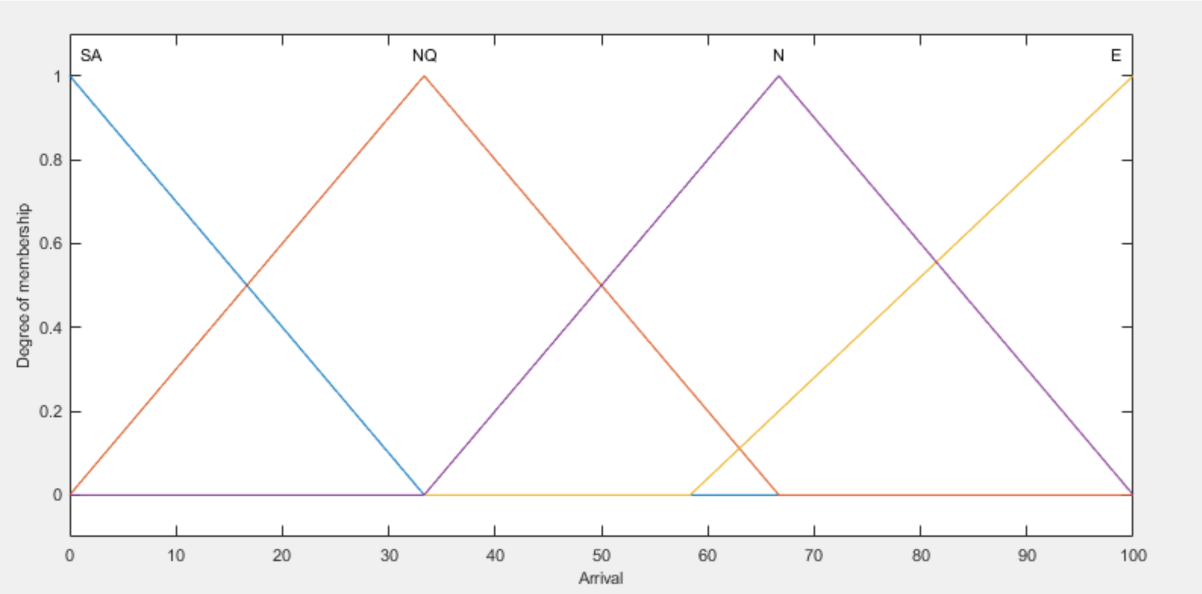


Figure: Graph of Membership function for ‘Arrival’ Input

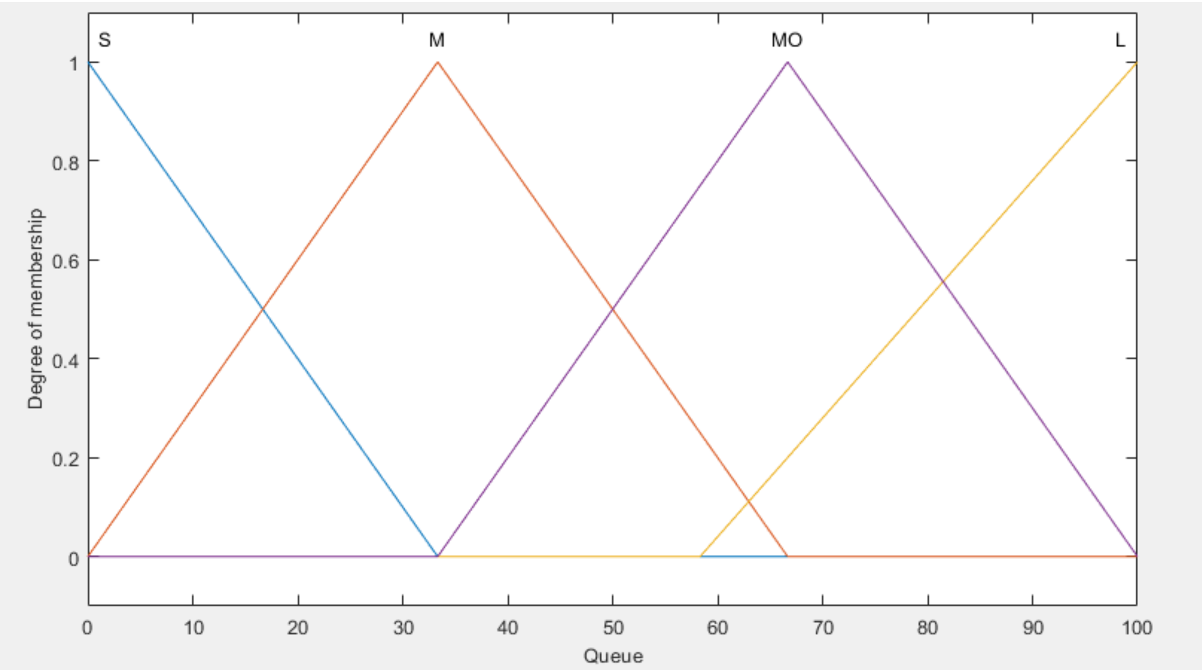


Figure: Graph of Membership function for ‘Queue’ Input

3.2 Composition & Inference

Fuzzy systems include a number of inference rules which connect the input fuzzy variable into output fuzzy variable. These rules govern our entire system and forms the basis of our entire design making system.

Based on the set of linguistic variables (Table 1), two inputs and one output, we can design the rules for 3 fuzzy variables regulating the fuzzy controller process as follows:

1. If **(Arrival is Scarcely-Any)** and **(Queue is Minor)** then **(Extension_Time is Zero)**
2. If **(Arrival is Scarcely-Any)** and **(Queue is Moderate)** then **(Extension_Time is Zero)**
3. If **(Arrival is Scarcely-Any)** and **(Queue is Large)** then **(Extension_Time is Zero)**
4. If **(Arrival is Not Quite)** and **(Queue is Slight)** then **(Extension_Time is Short)**
5. If **(Arrival is Not Quite)** and **(Queue is Minor)** then **(Extension_Time is Short)**
6. If **(Arrival is Not Quite)** and **(Queue is Moderate)** then **(Extension_Time is Zero)**
7. If **(Arrival is Not Quite)** and **(Queue is Large)** then **(Extension_Time is Zero)**
8. If **(Arrival is Numerous)** and **(Queue is Slight)** then **(Extension_Time is Medium)**
9. If **(Arrival is Numerous)** and **(Queue is Minor)** then **(Extension_Time is Medium)**
10. If **(Arrival is Numerous)** and **(Queue is Moderate)** then **(Extension_Time is Short)**
11. If **(Arrival is Numerous)** and **(Queue is Large)** then **(Extension_Time is Zero)**
12. If **(Arrival is Enormous)** and **(Queue is Slight)** then **(Extension_Time is Longer)**
13. If **(Arrival is Enormous)** and **(Queue is Minor)** then **(Extension_Time is Medium)**
14. If **(Arrival is Enormous)** and **(Queue is Moderate)** then **(Extension_Time is Medium)**
15. If **(Arrival is Enormous)** and **(Queue is Large)** then **(Extension_Time is Short)**

3.3 Defuzzification

In a Mamdani-type method, to compute a final crisp output value, the combined output fuzzy set is defuzzified using Centroid defuzzification which returns the center of area under the curve. If you think of the area as a plate of equal density, the centroid is the point along the x axis about which this shape would balance.

Centroid of Area Z_{COA}

$$z_{\mathrm{COA}} = \frac{\int_Z \mu_A(z) z \, dz}{\int_Z \mu_A(z) \, dz},$$

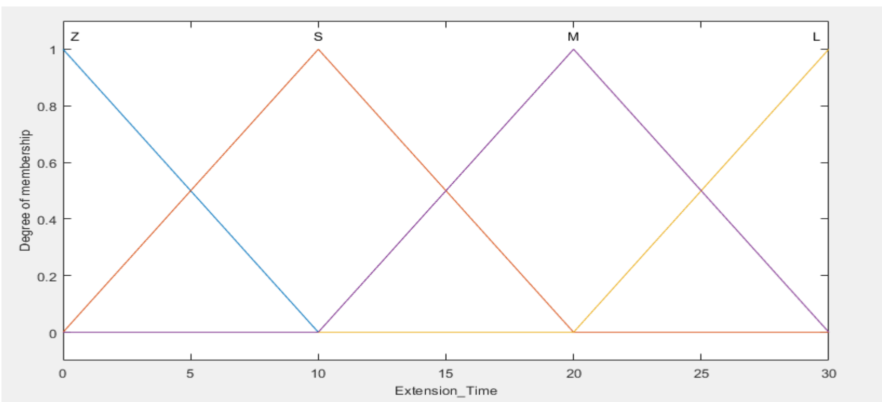
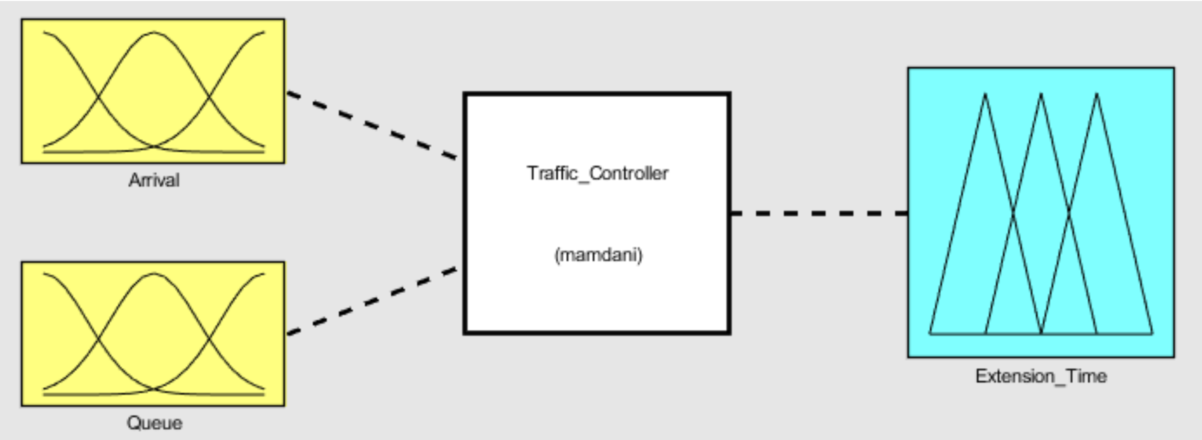


Figure: Graph of Output

4 *Mamdani* Fuzzy logic Controller using MATLAB

The following *Mamdani* Fuzzy logic controller was designed in MATLAB using fuzzy logic tool box.

Figure: Fuzzy Logic Control



1. Membership Function Editor: The first in designing the fuzzy variable are both input and the output. We edit membership associated with both the input and output using the GUI present.

2. Rule Editor: The rule editor is used to feed rules for into the Fuzzy Inference System (FIS).
3. Rule Viewer: The rule view is the tool used to analyse the rules and display the output of the system.

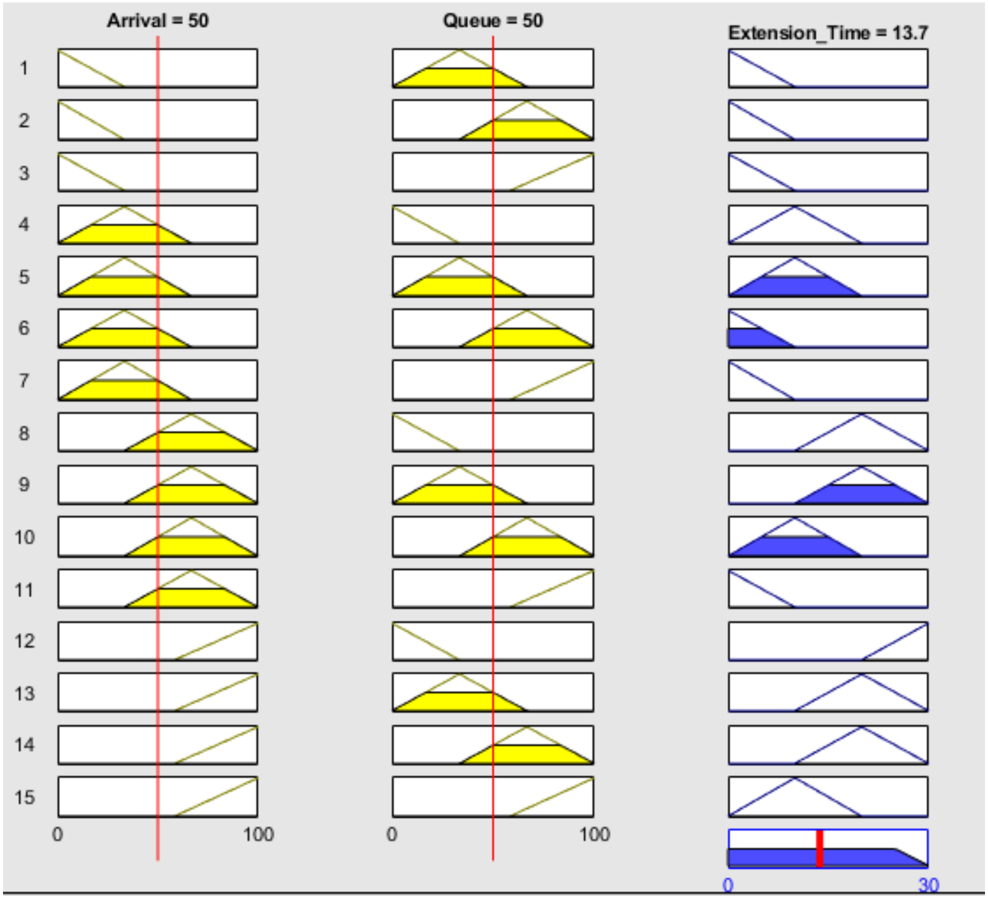


Figure: Rule Viewer

4. Surface View: The surface view is a surface analysis of the relationship between input and output variables

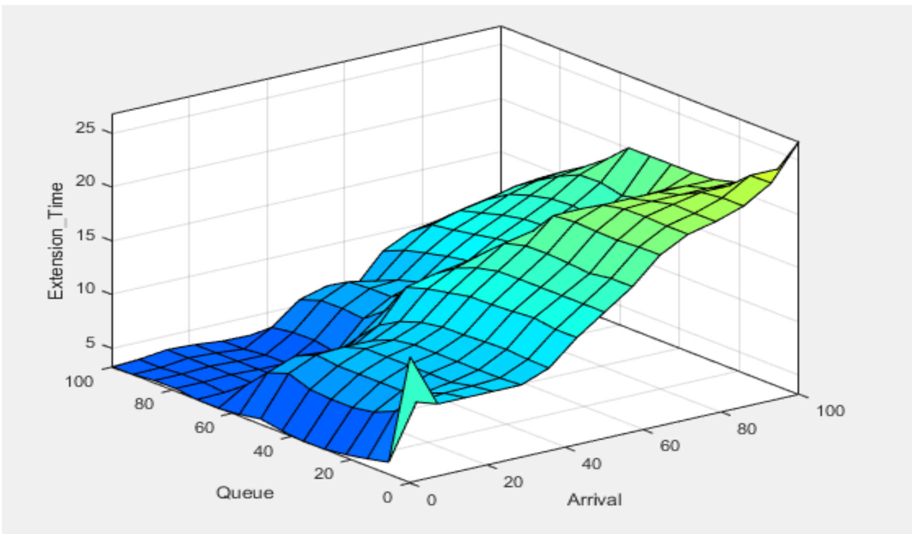


Figure: Surface viewer of fuzzy logic variables

5 Conclusion

On the basis of MATLAB simulation we can conclude that a fuzzy logic controller for a Traffic Control System is justified because, in a conventional traffic light control system, the lights change colour only after a fixed time duration regardless of the situation. The fuzzy logic controller is able to simulate Human Reasoning in the following way: If there are more cars waiting on a certain lane than the number of cars arriving in the other lane, increase the green signal duration for the first lane and/or decrease the green signal duration for the second lane. The fuzzy controller lets us model the concepts of ‘more’ and ‘less’ into the traffic control system. Also, if we have an emergency vehicle stuck in a lane, then a conventional system won’t be able to prioritize green light for that lane as it would stick with its steady duration rule.

Fuzzy Logic allows us to change that by incorporating the values of electromagnetic sensors installed for every path which counts how congested that individual lane is, which subsequently helps in the decision making of the logic as then the Fuzzy Controller would make sure than the amount of duration for Green Light is higher on that path. This can help in decongestion of lanes and making the quicker movement of traffic on roads, and can also be instrumental in saving lives as it helps in the movement of emergency vehicles.

6 References

[1] Goyal, M., Priya, A., Kumar, C., Verma, V. and Hota, M. (2018). An Ingenious Traffic Control System Using Fuzzy Logic Control With Emergency Override Feature. *2018 IEEE International Conference on System, Computation, Automation and Networking (ICSCA)*.

[2] Prontri, S., Wuttidittachotti, P. and Thajchayapong, S. (2015). Traffic signal control using fuzzy logic. 2015 12th International Conference on Electrical Engineering/Electronics, Computer, Telecommunications and Information Technology (ECTI-CON).