Smart Traffic Light System to Control Traffic Congestion PJAEE, 17 (9) (2020) Smart Traffic Light System to Control Traffic Congestion

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Smart Traffic Light System to Control Traffic Congestion

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Keywords: Traffic congestion; fuzzy controller; fuzzification; fuzzy inference; defuzzification; IoT sensors.

Abstract

Even with well-planned road systems and sufficient infra, traffic congestion is one of the major problems in the metro cities. The main reason for this problem is ever increasing number of the vehicles on road by 20% per year. In the current scenario, most of the traffic control systems used is of fixed cycle type which gives a constant phase for red/yellow/green for each signal cycle. Apart from using these controllers, an additional traffic policeman is also deployed in case of heavy traffic densities to control the traffic flow. These static systems cannot adapt to the dynamic situation which a traffic man can do in a real time situation. Deployment of traffic policeman at every junction is not feasible due to shortage of manpower and cost consideration. There is an urgent need of building a smart system which can automate and control the traffic. In this work, a three input fuzzy logic controller with the IOT sensors is proposed to adapt the real time dynamics of the traffic at a junction and reduce the congestion. Proposed fuzzy logic controller has three inputs namely, queue length, remaining time green and peak hours and one output parameter, time extension which is controlled by the three input parameters. All four lanes have been allocated 60 seconds of fixed time for green signal at the start. Increase/Decrease of the green light is done dynamically with ± 34 seconds. When compared to conventional controller, proposed approach gives a minimum improvement of 13% to a maximum improvement of 58%.depending upon various traffic conditions at the junction. In terms of average wait time delay it reduces the time delay by 40% in comparison to conventional systems and in terms of average trip time proposed approach is compared with UCONDES & OVMT approaches and improvement of 125% and 24.19% is observed.

Keywords: Traffic congestion; fuzzy controller; fuzzification; fuzzy inference; defuzzification; IoT sensors.

1. Introduction

With increase in the number of vehicles on the road, Traffic congestion has become one of the major problems faced across the globe. There are multiple reasons contributing to the traffic congestion problem which are shortage of infrastructure, traditional traffic light systems which uses fixed time interval [28]. These fixed time controller are not helpful in tackling the dynamic real time traffic needs. They only work well when the traffic density on the road is not changing quickly. To adapt to the real time traffic conditions, modern traffic control systems use the time division on each phase assigned to a total cycle time. Most of the traffic lights used today are based on one of three mechanisms to control traffic namely, pre-timed based signal control, traffic actuated based signal control and adaptive controller based signal control. In majority of situations, traffic lights have either pre-timed controller or traffic actuated based controller to control the flow of vehicles. Pre-timed signal controllers have a fixed time allocated to each artery for green time duration. These controllers perform very poorly when the traffic conditions are either very heavy or very light and are unable to adapt to the situation dynamically. Traffic actuated based controller performs a little better than the pre-timed controller in terms of average delay but they also have a very limited ability to respond to real time traffic. With the use of adaptive algorithms and communication devices like IOT sensors, modern traffic light systems are able to provide better solution to this problem. To overcome the deficiencies of the first two approaches, various adaptive controllers have been proposed and developed. Adaptive algorithms perform much better than the first two approaches and can adapt to the real time traffic situations by increasing/decreasing the time for the green phase at the junction to control the flow of traffic. In case of heavy traffic densities, time for the green signal is increased and vice-versa for light traffic. Fuzzy logic based adaptive controllers have been widely proposed by the earlier researchers. Fuzzy logic based modeling uses If-then rules and are better at modeling the qualitative aspects of the human knowledge and reasoning process without requiring precise quantitative analysis. Conventional mathematical models are not suitable for real time traffic systems as they are not able to adapt the dynamics of the problem and are full of uncertainties.

Arrival of vehicles is characterized by non-stationary characteristics at an intersection point and varies a lot during different timings of the day at various intersections. Multi Agent Systems (MAS) with distributed AI (DAI) [28]-[30] provides a better approach and solution to the problem. It is a multi-disciplinary system and provides optimum results. Use of modern adaptive controllers with Multi Agent Systems have outplayed the mathematical modeling simulations because developing a generalized mathematical model of an intersection to calculate the required green time for specific traffic demand is very difficult. Further traffic conditions at the neighboring traffic signals to the junction in consideration, have pseudorandom behavior which further adds to this problem. It is difficult to predict the change in the state of the traffic by using a specific traffic signal control parameter say queue length. This necessitates the use of more than one traffic signal control variable to better adapt the dynamics of traffic flow at an intersection point. Main objective of traffic control management is to reduce the overall average delay and to increase the mean speed of vehicles which requires an optimal green time required at each intersection. Optimal green time calculation for each intersection depends on the current traffic load and future predicted value.
The real time data is processed and manipulated by a fuzzy logic controller for controlling the timing of the traffic signal. The main reason behind using fuzzy logic

controller for the traffic problem is its relevance to human expert knowledge. It can mimic the human intelligence for controlling the vehicle flow at a junction and implements the real life rules in a simpler way in which humans think. Fuzzy logic controller can be used to grade the Uncertainties and imprecision in a specific domain of knowledge as traffic control. These graded concepts are vital for controlling traffic flow since real time traffic conditions at the signalized traffic intersection are neither deterministic nor described precisely. Domain specific knowledge and experience of traffic control are quite crucial for the design of fuzzy traffic controller in formulating linguistic protocols which generates the control input to the traffic signal control system. A fuzzy system outputs in a certain degree of true or false and is a classical artificial intelligence technology to solve problems in many fields like robotics, industrial control, home appliances etc., including traffic signal management.

In this work a three-input fuzzy controller is proposed which can adapt the dynamics of real time traffic and reduce the congestion at the traffic light junction. Proposed fuzzy controller has three inputs namely, queue length, remaining time green and peak hours and one output parameter, time extension which is to be controlled by the use of the three input parameters. A fixed time of 60 seconds is allocated to all the four lanes at the start. Extension/decrease of the green light is done dynamically with ±35 seconds. Compared to conventional fixed cycle type, proposed approach gives a minimum improvement of 13% and a maximum of 58% depending on various traffic conditions at the junction. In terms of CO_2 emission improvement of 20% and 42.12% and in terms of fuel consumption improvement of 34.73% and 57.18% has been observed compared to UCONDES (Urban CONgestion DEtection System) and OVMT (Original Vehicular Mobility Trace) [32] respectively.

Rest of the paper is organized as follows. Section 2 gives the brief introduction the major findings of the work done by earlier researchers in the field of traffic control at signalized intersection particularly using fuzzy control. Delay model for arrival rate and calculation related to green time and traffic engineering covering the Poisson distribution used in the work are given in section 3-5 respectively. Section 6 gives the methodology applied in this work including fuzzy model used for the proposed three-input fuzzy traffic controller, fuzzy sets & membership functions for input and output variables and the rule base. Details of simulation and related calculations are given in section 7. Results are discussed in section 8 and finally, section 9 concludes the work.

2. Related work

Earlier many researchers have done research and contributed to the optimal signal control algorithms. Pappis and Mamdani [1] were amongst the first to discover fuzzy logic application in traffic and proposed an approach to control an isolated two-way intersection with no vehicle turning. Nakatsuyama et al. [2] extended the work done in [1] to two intersections. It was further extended to multiple lanes by Favilla et al. [3]. Mehan [4] proposed a simple fuzzy logic controller which was well suited for mixed traffic conditions. Kaedi et al. [5] proposed a new approach by introducing neuro-fuzzy network a two stage method for intersection signal. Apart from fuzzy logic modeling researchers have also proposed mathematical models to solve the traffic problem.

Webster [6] was first to proposed a mathematical model for calculating the green time for reducing the average delay of vehicles at the traffic junction. This model calculates green time offline based on the historical data of the signalized traffic intersection. Proposed approach, however, could not cater the sudden changes in the traffic load. These limitations were covered in [7]-[9] where researchers proposed real time vehicle actuated where mathematical optimization used to decide increase/decrease the green time phase, refinement gap extension process or relative time delays. Pranevicius et al. [9] proposed a fuzzy logic based traffic control which is used to control the timing of the traffic signal based on the real time traffic loads.

With the development of economical sensors like IOT devices, many researchers have proposed vehicle actuated methods which perform better than the previously proposed methods. They are subjected to loop detectors which are placed to appropriate positions near the signalized traffic intersection. The accuracy of detections is directly dependent upon the number of detectors deployed. A major limitation of these actuation based methods is that even a sparse traffic flow can increase the average delay of vehicle at the intersection since in these approaches a specified time block extension of green time is used. To overcome the problem of actuated based controllers, adaptive controllers were proposed. These controllers used present and past traffic history for determining the green time and use various techniques like neural networks, fuzzy logic, genetic algorithms or even hybrid approaches. Many approaches have been proposed in which the green time signal have been controlled on the real time traffic loads like SCOOT [10], RHODES[11, Sydney Cooperative Adaptive Traffic System (SCATS) [12], Green Link DEtermining (GLIDE) [13],[28] etc. In all these approaches, data is collected from the inductive loop detectors placed in the close vicinity of the traffic junction and then the decision is made to increase/decrease the timer based on this data. This communication between the sensors and centralized server requires an effective mode of transmission like wireless approach. Huge amount of real time data is to be communicated to centralized server which gives a limiting feature to these responsive approaches. Further this problem is alleviated due to increase size of networks. Choy [14] addressed this by proposing a multi-agent hierarchical system which reduces the communication overhead by providing more data to the intersection agents, which was monitored by regional agents.

Askarzade et al. [15] proposed a fuzzy logic approach with sensors on a four lane traffic junction. Sensors were applied on all the four lanes of the junction for counting the vehicles in the queues. Ehsan Azimirad et al. [16] have used sensors to calculate queue size and number of vehicles per lane as two input parameters to calculate the time extension of the signal. Kapileswar Nellore et al. [17] proposed a wireless network comprised of sensors to control the traffic in urban areas. Ayesha Atta et al. [18] proposed a model based on IoT sensors and fuzzy logic design to control the traffic signal. IoT and Arduino chip which fetches the data for input parameters of fuzzy control for controlling the extension time. Eze et al. [19] proposed a fuzzy logic based model designed on C++ for simulation of the isolated junction with the use of electromagnetic sensors. Through sensors, data is collected for the processing in the fuzzy logic based controller to control the extension time. Mario Collotta et al. [20] proposed a phase sorting module based on real time data to calculate time phase for the current queue with the use of wireless sensor network for and fuzzy logic controller to control the extension. This system uses priority based controlling algorithm which is very unique to other counterparts wherein normal system of traffic signaling is used and provided a good approximation of the time extension control of the signals. Yan Ge et al. [21] proposed a model based on the traffic urgency which consists of two stage traffic signal control on a single intersection. Multi-Agent Systems (MAS) have used GLIDE, DAI (Distributed AI) and MAS to control the traffic and observed good results compared to the static light systems [22]-[24].

3. Fuzzy Sets

In this section, type-2 fuzzy sets and defuzzification procedures are briefly explained. Type-2 fuzzy sets are used to handle more uncertainty and to generalize standard type-1 fuzzy sets and systems [31]-[32]. Type-1 fuzzy sets membership function equation 1 is given below. It is more a certain function and has no uncertainty at all:

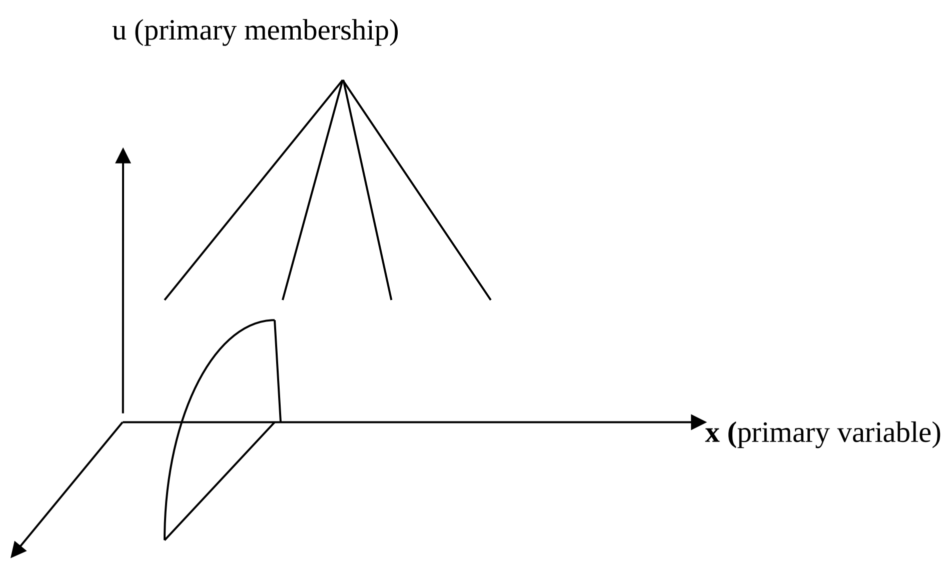
$$A = \{(x, \mu_A(x)) | \forall x \in X\} \qquad (1)$$

where $\mu_A(x)$ is called the membership grade of the values associated with x and it belongs to the interval (0,1). This defines the partial set of input truths in the primary domain.

Zadeh [23] proposed type-2 fuzzy sets which handles uncertainty by assigning a range of partial truth values to the input values associated with it whereas type-1 fuzzy set can only capable of assigning crisp values to them. The type-2 fuzzy set system can be represented by Ã and is given by the equation 2 below:

$$\tilde{A} = \{((x,u).\mu_{\tilde{A}}(x,u)) | \forall x \in X, \forall u \in J_x \subseteq [0,1]\} \qquad (2)$$

where X is the domain of the fuzzy set Ã and J_x is the secondary domain at x and $\mu_{\tilde{A}}(x,u)$ ε {0,1}. Compared to type-1 fuzzy sets, type-2 fuzzy sets have 3-dimensional membership function, where third dimension contains value of the membership function at its every point on two dimensional domain which is also known as footprint of uncertainty (FOU). Figure 1 shows the membership function of type-2 fuzzy set.



(Third dim)

Figure 1: Membership function of interval type-2 fuzzy set

After assigning the uncertain set values to the input, next step follows is defuzzification of the membership function. Defuzzifying type-2 fuzzy sets is a bit complex procedure [12]. This complexity is reduced when interval type-2 fuzzy sets are introduced. The interval type-2 fuzzy sets have a third dimension between the membership function and variable which is shown in figure 1 and known as footprint of uncertainty (FOU) [13].

For an interval type-2 fuzzy set, value of third dimension is same everywhere which is 1, which states that there is no new information available in it. So the third dimension is ignored for the above set and only FOU is considered. Due to this reason, interval type-2 fuzzy set is also called first order uncertainty fuzzy set whereas general type-2 fuzzy set with its third dimension meaningful is called as second order uncertainty fuzzy set.

4. Traffic Engineering

Traffic Engineering falls under the larger scope of transportation engineering. It is a branch of civil engineering that uses techniques to successfully move people and goods without creating congestion on the roads. Main focus of traffic engineering is on the research and building immobile infrastructure like roads, railway tracks, bridges, traffic signs and signals for the convenient movement. To achieve this, construction of static elements like roads etc. and dynamic elements are also important. Dynamic elements like IOT sensors', interconnected guidance systems are really helpful and working in reducing congestion during different hours of the day like peak hours.

The relationship between the flow of vehicles in a lane (L) (vehicles per hour), maximum driving speed of vehicles (V) (km/hr) and density (D) of the lanes (vehicles per kilometer) is given by equation (3) below:

$$L = D*V \tag{3}$$

In traffic flow model at a traffic junction, arrival of vehicle is an important aspect and has an important application in traffic flow simulation [29-30]. Vehicle arrives at a traffic junction in a random process as sometime many vehicles come together while they come sparsely at some other time. Arrival of the vehicles, need to be characterized statistically at a traffic junction which are modeled in two interrelated ways. In First kind of modeling a suitable continuous distribution can be used to calculate the time interval between the successive arrivals of vehicles. In Second kind of modeling suitable discrete distribution like Binomial, Poisson etc. can be used to calculate the number of vehicles arrived in a give interval of time.

In this work, we have considered that vehicles arrive at a traffic junction randomly and follow Poisson distribution and not the binomial distribution. In binomial distribution, it is found that there is a sample of definite size, making it possible to count the number of times an event is observed. Poisson distribution is very suitable when number of times an event, say arrival of vehicles, is known but not how many times it does not occur.

The function of Poisson distribution is as follows:

$$P(r) = e^{-m} * (m^r/r!), \quad r = 0, 1, 2, \ldots. \tag{4}$$

where, P(r) is the probability of vehicles arrived randomly where r = 0,1,2,3,…,n, e is the base of the system of natural logarithm having standard value of 2.7183, m is the average number of vehicles during time t and r! has usual meaning of r*(r-1)*(r-2)*…3*2*1.

$$m = \lambda t \tag{5}$$

Where λ is the average arrival rate of vehicles in a unit time and t is the duration of each counting interval. Equation 6 can be rewritten as:

$$P(r) = e^{-m} * (\lambda t^r/r!), \quad r = 0, 1, 2, \ldots. \tag{6}$$

5. Methodology

Figure 2 shows the general diagram of intersection of traffic at a junction with four directions. A fuzzy logic-based controller is proposed with three input parameters namely Queue_length, Rem_time_green and Peak_hours and one output parameter, Time_extension. Queue_length refers to the length of the vehicles in the queue behind the signal. Sensors capture the length of queues in each lane and pass the data into the fuzzy controller. Fuzzy sets of queue length have been taken as very_less, less, medium and long. Length between 0 – 4 meters refers to very_less, 0 – 8 meters as less, 4 – 12 meters as medium and more than 8 meters as long. Second input parameter, rem_time_green, has 4 fuzzy sets as very_less, less, medium and large. Rem_time_green is the time remaining for the green signal before turning to red. This is a very decisive factor for controlling the time extension of the signal. It is calculated as a fraction of the full time which is fixed as 60 seconds in all the lanes. Remaining time green as 0 – 0.25 is taken as very_less, 0 – 0.5 as less, 0.25 – 0.75 as medium and greater than 0.5 as large. Peak_hours refers to the different time durations of the day. This factor is also very crucial for controlling the extension of the signal as most of the conventional signals are not considering the time duration of the day for passing the vehicles due to which long waiting queues occur during the peak hours. Peak_hours consists of five fuzzy sets namely,very_light, heavy_morning, medium, heavy_evening, light. Time duration from 11:00 PM – 7:30 AM is taken as very_light traffic conditions as most of the roads don't have much traffic density during this period, heavy_morning timings are 7:00 AM – 11:30 AM in which most of the traffic is active, medium timings are 11:00 AM – 4:30 PM, 4:00 PM – 8:30 PM is taken as heavy_evening as this is that duration of the day where most of the traffic density occurs and 8:00 PM – 12:30 AM as light traffic conditions. Output of the fuzzy control system is Time_extension which is to be controlled by the use of the three input parameters. All four lanes have been allocated a fixed green signal time of 60 seconds at the start. Time_extension is done dynamically in the running queues after analyzing the three input parameters. Extension/decrease of the green light can be done up to ±35 seconds, i.e. the range of time duration of green time is in the interval ϵ {25, 95} seconds. Five fuzzy sets have been taken for the Time_extension as more_decrease, decrease, do_not_change, increase and more_increase. If the Rem_time_green and Queue_length is high in the running queue, time extension should be decreased and vice versa. Similarly, during heavy_morning and heavy_evening timings extension should be increased up to 95 seconds while during very_light conditions it should decrease to 25 seconds. Extension of time is done by keeping in mind the state of other queues as well to provide a better optimized solution to the problem.

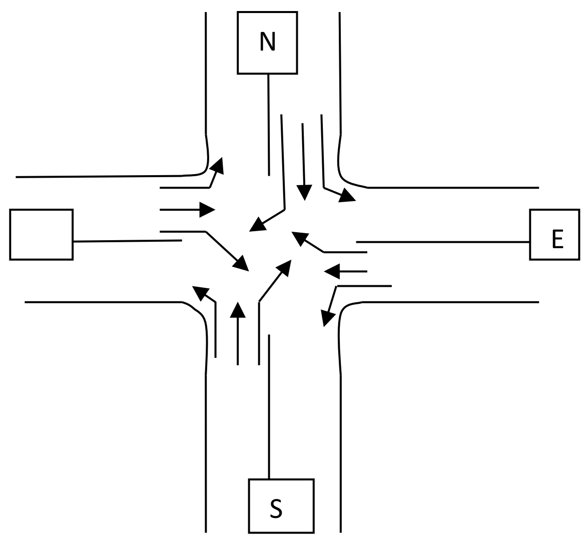


Figure 2: Traffic intersection at a junction (general diagram)

Proposed model has three sub procedures, i.e. fuzzification, fuzzy inference and defuzzification. During fuzzification, crisp values are converted to fuzzy sets with the help of membership functions of type-2 fuzzy sets. Then these fuzzy sets are passed to the rule base which are *if-then* statements, having the general format as:

If {Queue_length is medium} *and* {Rem_time_green is large} *and* {Peak_hours is Heavy evening} *then* {Time_extension is increase}

Figure 3 shows the fuzzy block diagram and the fuzzy sets of the input and output variables are shown in table 1.

Defuzzification is the last step of the proposed model in which crisp output values are calculated using the fuzzy rule base. It is the inverse step of the fuzzification. Mamdani based inference with centroid defuzzification is used to convert the fuzzy sets to crisp values. Various membership functions of the input and output parameters are shown in figures 4 – 7.

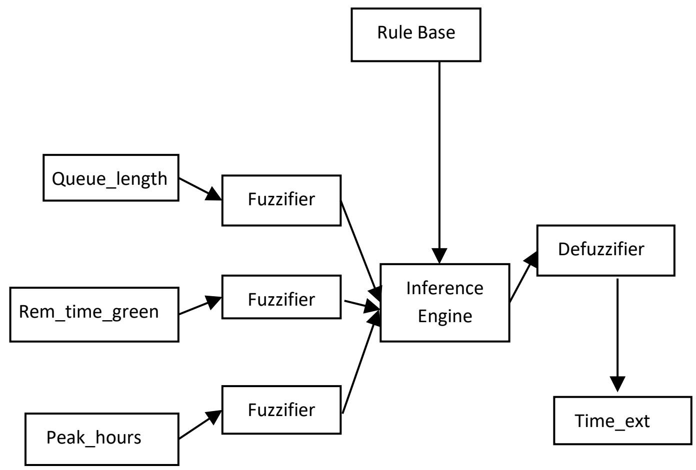


Figure 3: Fuzzy Model block diagram

Table 1: Input and Output variables and their Fuzzy sets

Input/Output Variables	Fuzzy Sets
Queue_length (Input)	ϵ{very_less, less, medium, long}
Rem_time_green (Input)	ϵ {very_less, less, medium, large}
Peak_hours (Input)	ϵ {very_light, heavy_morning, medium, heavy_evening, light}
Time_extension (Output)	ϵ {more_decrease, decrease, do_not_change, increase, more_increase}

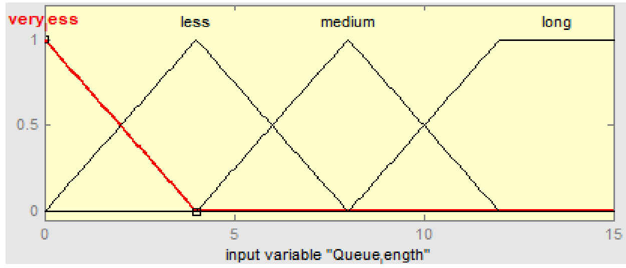


Figure 4: Membership function of input parameter Queue_Length

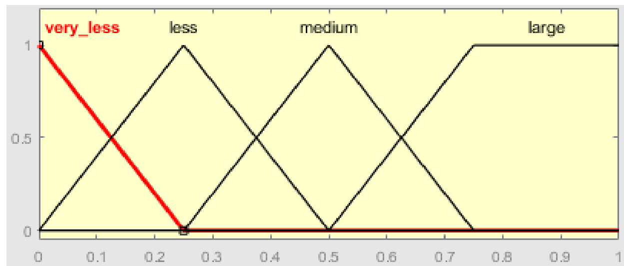


Figure 5: Membership function of the input parameter rem_time_green

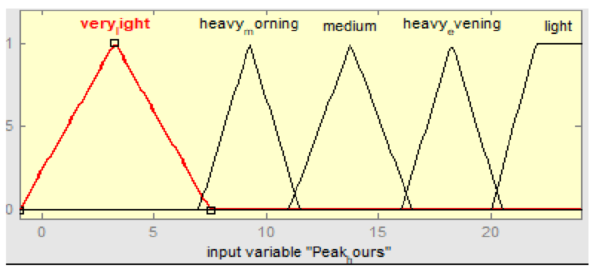


Figure 6: Membership function of the input parameter Peak_hours

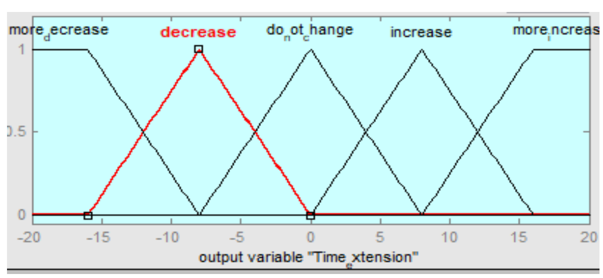


Figure 7: Membership function of output parameter Time_extension

Rule base of the fuzzy set is shown in the table 2. There are total 80 rules (4*4*5=80) in the rule base from which extension of timer is calculated.

Table 2: Rule base of the Fuzzy inference

Rul	Queue_length	Rem_time_green	Peak_Hours	Time_extension

e n o .				
1	Very_ less	Very_les s	Very_li ght	Do_not _chang e
2	Very_ less	Very_les s	Heavy_ mornin g	Decrea se
3	Very_ less	Very_les s	Mediu m	Decrea se
4	Very_ less	Very_les s	Heavy_ evening	Decrea se
5	Very_ less	Very_les s	Light	Decrea se
6	Very_ less	Less	Very_li ght	Decrea se
7	Very_ less	Less	Heavy_ mornin g	Decrea se
8	Very_ less	Less	Mediu m	Decrea se
9	Very_ less	Less	Heavy_ evening	Decrea se
1 0	Very_ less	Less	Light	More_d ecrease
1 1	Very_ less	Medium	Very_li ght	More_d ecrease
1 2	Very_ less	Medium	Heavy_ mornin g	More_d ecrease
1 3	Very_ less	Medium	Mediu m	More_d ecrease
1 4	Very_ less	Medium	Heavy_ evening	More_d ecrease
1 5	Very_ less	Medium	Light	More_d ecrease
. .	. .	. .	. .	. .
7 9	Long	Large	Heavy_ evening	Increas e
8 0	Long	Large	Light	Do_not _chang e

Figure 8 and 9 describes the working of the IoT model. Proposed approach has been implemented with the use of ultrasonic sensors.

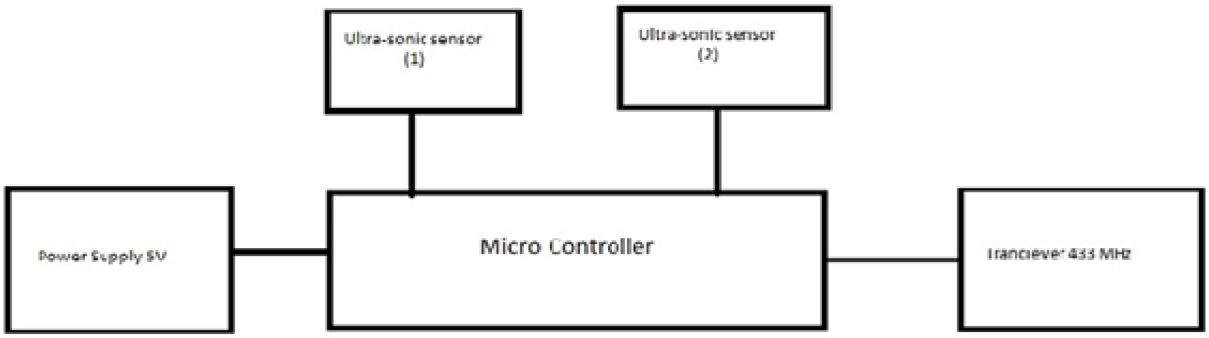


Figure 8: Block diagram of microcontroller

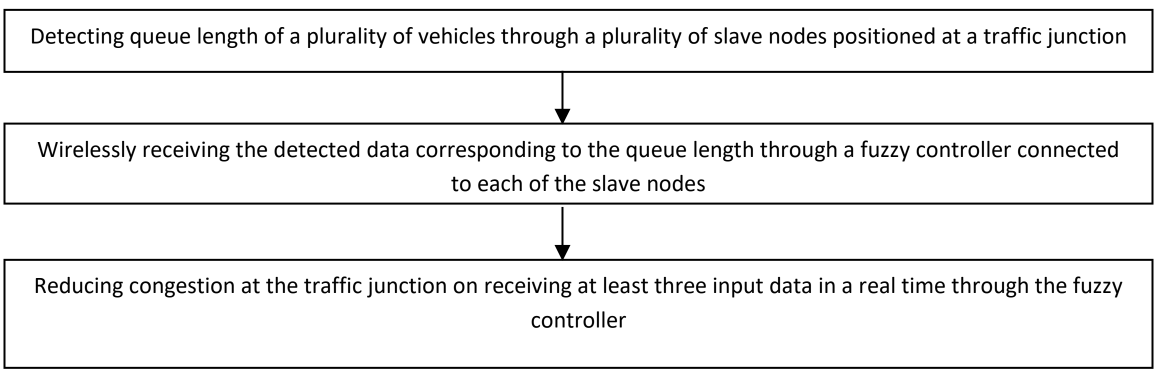


Figure 9: Work-flow of the IOT Model

In the proposed approach, WSN's outplayed the wired approach as they are more efficient in terms of power consumption and more effective in deploying in a real time scenario. Each RF sensor is deployed in a lane with 2 repeaters to reduce the overall costs. The total lane length measured with the sensors is 150 meters in each lane. Wireless sensors are more reliable and robust in adverse climate conditions. Communication between the nodes for sending and receiving information occurs through a wireless link with a R_x and T_x channel. Wireless links can be provided with WLAN's, Wi-Fi module or Bluetooth which consumes very low power with respect to their wired counterpart. Performance of RF sensors depends upon the operating frequency of the sensors and the interference of the radio frequencies from the physical environment. Therefore, choosing the right frequency for the sensors in a model is a key step for ensuring the optimum performance of the architecture.

6. Simulation and calculations

Simulation is done using MATLAB 8.1 with fuzzy logic toolbox built-in. There are two reasons for using fuzzy logic toolbox. Firstly, this toolbox can form rule base very easily and quickly and can be changed easily if required later on. Secondly, overall time is reduced for developing the rule base. While deriving resultant outputs following assumptions have been made:

1. A Cross-junction is taken with each arm having four lanes.

2. Duration of green light is fixed to 60 seconds that can be varied from -28 to +28 seconds hence the range of the controlled timer is ϵ {32, 88} seconds.

3. Pedestrian crossing is considered.

4. Queue length has been measured by the sensors placed at the intersection of each arm.

5. Vehicle inter-arrival is independent to other vehicles.

7. Results and Discussion

Table 3 shows the ten different real time values of the input parameters taken at different intervals of the day. These ten values are random sample taken from the complete list of values calculated by applying the proposed approach to the system. From the observation, it is found that Peak_hours is the most important parameter for deciding the extension of the timer of the signal. When the time is 11:30 PM (light), Queue_length is less and Rem_time_green (less), time extension is decreased to 51.39 seconds too reduce the waiting time of the other queues but in case of conventional timers, it would have been 60 seconds and there would be extra 8.21 seconds waiting time for the other queues. Similarly for the time 9:30 AM (heavy_morning), both the Queue_length and Rem_time_green values are large and medium, there is an increase in the timer of additional 16.3 seconds to clear up the running queue as it is a peak time for traffic but in case of conventional timer, it would only be green for 60 seconds which piles up the queue and waiting time for each vehicle is increased drastically. When the Peak-hours is 12 midnight, value of Queue_length and Rem_time_green are medium, extension of the timer is decreased to 25.2 seconds to reduce the waiting time of the other queues because at midnight, there is not much density of traffic on roads which saves waiting time of the vehicles and fuel as compared to its conventional counterpart.

Table 3: Real time values and comparison between fuzzy and non-fuzzy

Queue_Length	**Rem_time_green**	**Peak_hours**	**Time_extension**	**Conventional**	**Difference**	**% improvement**
4	0.3	23.5	60-8.21=51.39	60	-8.21	-13.68
14	0.4	9.5	60+16.3=76.3	60	16.3	27.16
16	0.2	10	60+21.4=81.4	60	21.4	35.67

16	0.3	11.5	60+17 =77	60	17	28.33
10	0.5	14.5	60+8= 68	60	8	13.33
4	0.3	15.5	60- 15.3=4 4.3	60	- 15. 3	-25.5
12	0.3	15.5	60+18 =78	60	18	30
12	0.1	16.5	60+21 =81	60	21	35
12	0.2	19.5	60+21 =81	60	21	35
8	0.5	12 (mid nigh t)	60- 34.4=2 5.2	60	- 34. 4	- 57.33

Table 4: Comparison of proposed approach with UCONDES & OVMT approach [28] in terms of trip time and waiting time

Approach	**Trip time (per 1000 vehicles) in secs**
UCONDES	6000
OVMT	6200
Proposed approach	1500
% improvement	25% (UCONDES) 24.19%(OVMT)

Proposed approach has been compared with UCONDES and OVMT approach for calculating average trip time of a vehicle for fixed distance. In our calculations, we have taken 10 km as a average distance for each vehicle and there is a signal at every 1km on the road and for each cycle of signal to become green in all the lanes, each vehicle has to wait 180 seconds for its turn to cross the junction. Our results shows that the proposed approach is better than the above two approaches in terms of reducing the trip time by 25% in comparison to UCONDES and 24.19% in comparison to OVMT.

8. Conclusion& Future Work

To reduce traffic congestion which is a major problem faced in the entire major cities today, in this work a three-input fuzzy controller is proposed which can adapt the dynamics of real time traffic and reduce the congestion at the traffic light junction. Arrival of vehicles at a traffic junction has been considered random and follows

Poisson distribution. All four lanes are allocated a fixed green signal time of 60 seconds at the start. Green time extension was done dynamically in the running queues after analyzing the three input parameters. Extension/decrease of the green light had been done up to ±35 seconds. Total 80 rules in the rule base have been formed from which extension time was calculated. Simulation is done using MATLAB 8.1 wherein fuzzy logic toolbox has been used.

Proposed fuzzy approach gives better results compared to the conventional traffic system. Compared to conventional fixed cycle type, proposed approach gives a minimum improvement of 13% and a maximum of 58% depending on various traffic conditions at the junction. In terms of trip time reduction improvement of 25% and 24.19% has been observed compared to UCONDES and OVMT [28] respectively. Proposed approach has used IoT devices providing a sustainable and economical product for saving time and fuel. Further, in the proposed work a four-lane traffic junction has been considered which can be extended to higher number of lanes too.

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