Cognitive Road Traffic Controller using Fuzzy Logic in Iot

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Abstract

*Road Traffic congestion is a critical problem in many cities which causes major distress to road users. This is due to increase use of vehicles which waits endlessly and causes traffic deadlock. Many traffic control systems have been developed to mitigate this problem. Now-a-days traffic demands are high and increasing due to increase in number of vehicles. We proposed a technique called Cognitive Road Traffic Controller (CRTC) which efficiently reduces the waiting time in traffic signal. This paper gives a brief discussion of the procedures we adopted to develop an intelligent fuzzy control system for dealing with the road traffic congestion problem. Specialized node known as Local Cognitive Node (LCN) implements the learning components and decision making. The system was developed using fuzzy logic technology and Cognitive sensor node where these nodes use learning mechanism to take decisions at LCN. Simulation results shows that problem of traffic congestion is efficiently reduced in the traffic network by using the proposed mechanism***.**

Keywords— *Wireless Sensor Networks, Traffic Congestion, fuzzy logic, fuzzy rules, Cognitive node***.**

I. INTRODUCTION

Recently, congestion has become one of the most serious transport problem in urban cities. However, adding new road capacity(extending road lanes) is not the solution to control the traffic congestion. In order to handle the traffic bottleneck effectively, traffic information such as slower speed of vehicles, number of vehicles in queue and motion and travel time should be supplied by various traffic detecting sensors. Many methods have been proposed by scientists and research communities to solve the problem of traffic congestion on highways as well as in the metropolitan cities. Computer scientists hunt to find out a better solution to solve this traffic problem. In this paper we use intelligent traffic control system which efficiently reduce the traffic congestion problem.

The Recent advancements in wireless communications and electronics have led to the development of WSNs. Wireless Sensor Networks consists of many sensor nodes which are connected with each other to a main location which passes data through a network. Sensor networks are highly scattered wireless networks in which nodes are small in size and light in weight. These nodes spread out in large numbers to supervise the environment or the system. The Internet of Things (IoT) is a system of inter-networking computing devices, embedded with software, sensors, electronics which has the capability to transfer the data across a network without human-to-human interaction or human-to-computer interaction.

Fuzzy logic has been successfully applied to a various industrial applications like intelligent systems like autonomous vehicles, chemical processes, human reasoning and enhancement of robotics. The fuzzy systems are knowledge-based expert systems or rule-based systems where decisions are made with if-then rules [1]. Fuzzy logic is used to draft the fuzzy control rules for traffic control system in different cases using linguistic variables. Fuzzy logic also ensures that traffic congestion is reduced even if it is not totally eradicated.

In our proposed system traffic congestion problem is solved dynamically in Local Cognitive Node (LCN). This can be achieved by using fuzzy logic and cognition in LCN for decision making. The fuzzy logic provides predicted traffic output with the 2 inputs, number of cars arrived and number of cars in queue. In LCN, aggregation is done with the predicted traffic output of 3 neighbouring signals as input to obtain aggregated output.

II. RELATED WORK

Fuzzy logic is mainly used for dealing with partial or half truth, where the values lies between "completely true "and "completely false". This technique is widely used in all industrial control and information processing applications. [2].

In [3] believed that electro-sensitive traffic lights that uses fuzzy tables had better efficiency when compared to fixed present traffic signal cycles as it was possible to extend or shorten the time of traffic light signal when the vehicle number changes either more or less. This paper was focused on designing an traffic signal using fuzzy control. The membership function usually take values between 0 and 1 in fuzzy were used to calculate the unpredictable number of vehicles, speed of the vehicle and extent of a road and also the volume of cars in traffic conditions were stored.

The earliest try to apply the fuzzy logic in order to control the traffic was made by [4]. A fuzzy logic controller has been implemented in two one-way streets which has only one intersection. Many similar researches have been done continuously and also reported better action of the fuzzy logic controllers compared to the pre-timed controllers [5].

The fuzzy logic model is totally based on the experience of the operator and not the technical understanding of the system since the first initiation of fuzzy logic by [6] [7] [13], fuzzy systems are being used to improve performance in control and decision making scheme and also in non-linear system modelling [8] [9] [10] industrial plant control, robotics, system identification and so on.

Tan et al [11] describes the representation and performance of an intelligent traffic light controller based on fuzzy logic rules. The research workers developed a software based on this technology to simulate the condition of a isolated traffic junction. The simulations results provided a comparison between the fuzzy logic controller and a conventional fixed-time controller; and thus the result proved that the former one had better performance both in terms of time and cost.

U. C. Osigwe et al [12] designed an intelligent traffic control system in order to keep track of road traffic and also to control the traffic in that location. A new methodology called as Structured Systems Analysis and Design Methodology (SSADM) and the Fuzzy-Logic based Design Methodology was used in this system. These system [14] do not have the capability to handle the traffic problems which occurs at cross-junctions. Thus our design was implemented a new system which is sensor based to solve these problems.

III.SYSTEM MODEL

In this system, the traffic problem is solved by providing fuzzy logic approach where the signal timing can be changed so that there will be no delay in the traffic region.

This is done with the help of two input values namely the number of cars in queue and arrival of cars. We consider the input values from three signals of a particular region and then aggregate those values to get the predicted traffic of a single signal.

The predicted traffic of one signal will be differentiated in 5 different variables and each and every variable defining its own change of timing in the traffic system.

There are three inputs and each of the input has 3 membership functions, thus have 3 * 3 = 9 rules.

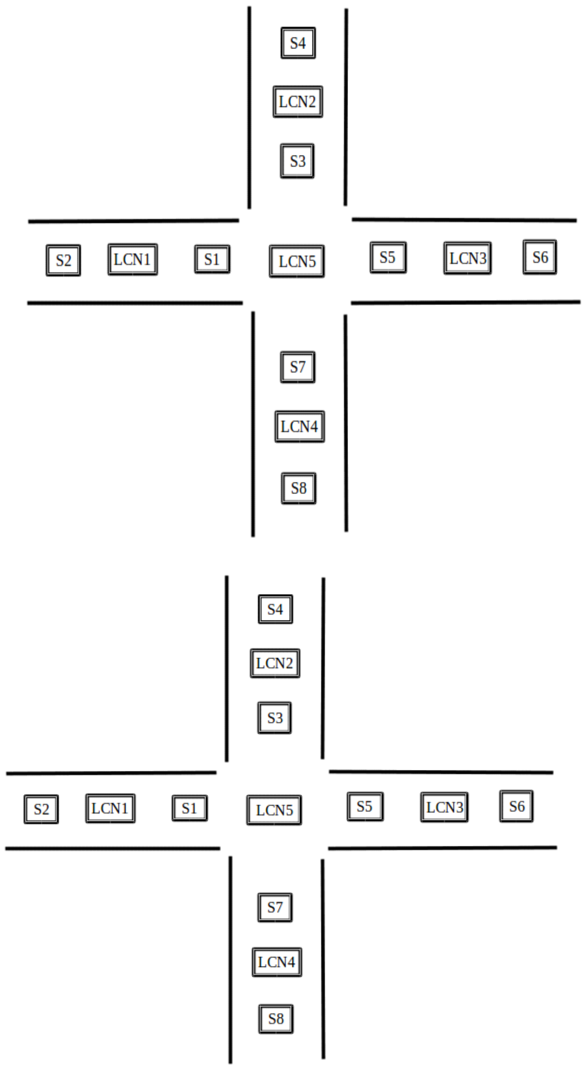

Fig. 1. System Architecture for CRTC

The transformation from a fuzzy set to a crisp value is called defuzzification.

All these data collected from sensor nodes are stored in LCN (Local Cognitive Node). With these collected inputs we perform the fuzzy operation and then aggregate them and store it in the local cache of LCN.

Fuzzy logic is used in mapping the inputs to the output values, and the primary mechanism is formulating the if-then statements known as rules. All the fuzzy rules are evaluated in parallel manner, and the order of these rules is not important. These rules are beneficial because they refer to variables and the adjectives that describe those variables. The variables that are used in fuzzy logic system is called as linguistic variables.

Fuzzy Logic generalizes the Notion of true values in Classical Logic into Matter of Degree. A vital feature in fuzzy logic system is the approximate reasoning condition.

The defuzzifier converts the output fuzzy set into a crisp variable. It produces a non-fuzzy control action that represents possibility distribution of an inferred control action. The centroid method generates center of gravity of the final fuzzy control space. It provides a sensitive result to all the rules.

Many methods are available for finding this and we use centroid method here which is a best and mostly used. The output membership function is defined as

$$z^* = \frac{\int f_s(t).tdt}{f_s tdt}$$

Where, $f_s(t)$ is the membership function of set S.

The CRTC system model is shown in Fig. 1, where multiple sensor nodes are deployed but some act as LCN to take decision locally.

IV. PROPOSED SYSTEM

In our proposed system, the sensor nodes are deployed in traffic signals. There are two sensors for each and every signal. The first sensor node is placed behind the traffic light and the second sensor was placed at some distance away from the first sensor. The first sensor counts the number of vehicles passing the traffic light signal; the second sensor counts the number of vehicles coming to the intersection point. The sensors then calculate the number of cars for the input data and then give it to the fuzzy system.

The fuzzy inference system used here uses mamdani fuzzy system. Two inputs are given to the system to get the output. The inputs of this system are number of cars in queue and arrival of cars. The output is the change of the traffic time for green light where the traffic is very high.

The first input is arrival of cars in traffic signal. This input have 3 linguistic variables as small, medium and large. The overall range of this input is considered to be from 0 to 45. The linguistic variable range is taken as small (0 to 15), medium (16 to 30) and large (31 to 45). The arrival of cars is directly proportional to distance to the predicted output.
Fig. 2, describes the fuzzy membership function of arrival of cars in the traffic light signal.

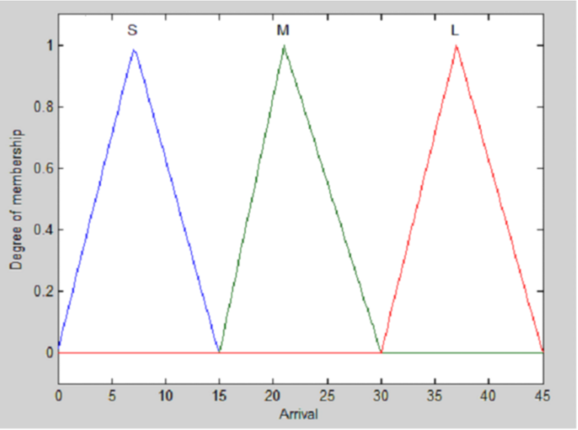

Fig. 2. Fuzzy Membership Function of Arrival of Cars

The second input is no of cars in the queue. This input have 3 linguistic variables as small, medium and large. The overall range of this input is considered to be from 0 to 45. The linguistic variable range is taken as small (0 to 15), medium (16 to 30) and large (31 to 45). The number of cars in queue is directly proportional to distance to the predicted output.

Fig. 3, describes the fuzzy membership function of arrival of cars in the traffic light signal.

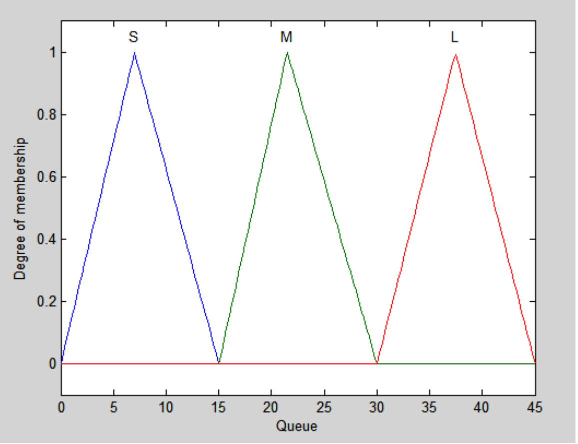

Fig. 3. Fuzzy Membership Function of Number of Cars in Queue

The output of this fuzzy inference system is the predicted traffic. The predicted traffic is set as the average size of the AOI i.e. 0 to 45. The output has five linguistic variables Very Small(VS), Small(S), Medium(M), Large(L), Very Large(VL). The member functions of the output are 1×R, 2×R, 3×R, 4×R, 5×R, 6×R, 7×R, 8×R, 9×R. Thus 9 rules are used to form the system. 1×R gives the smallest predicted traffic and 9×R gives the largest predicted traffic. The output of this fuzzy inference system is the predicted traffic of traffic light controller. Thus to find the predicted traffic fuzzy inference rules are applied to it. *Fig. 4*, gives the membership function of the predicted traffic output.

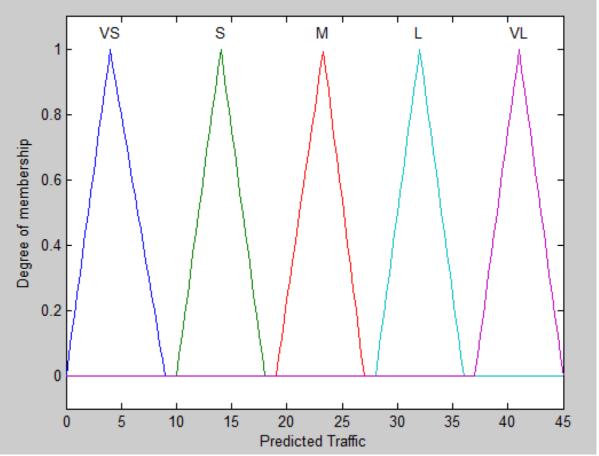

Fig. 4. Fuzzy Membership Function of Predicted Traffic Output

The range for each and every linguistic variable is divided between (0-45), The VS takes values from (0- 9), S has (10-18), M has (19-27), L has (28-36), VL has (37-45).

Table I. The Fuzzy Rule Base

NO	ARRIVAL	QUEUE	PREDICTED TRAFFIC
1	S	S	VS
2	S	M	S
3	S	L	M
4	M	S	S
5	M	M	M
6	M	L	L
7	L	S	M
8	L	M	L
9	L	L	VL

The table 1 is the fuzzy rule base for a single traffic light signal. In Local Decision Making in order to determine the output for a single signal we have to consider the output of three traffic light signals from the above fuzzy rule base.

The predicted traffic from the above table is the output for only one signal. Since we consider three signal predicted traffic to calculate one signal value we perform the operation of data aggregation.

Aggregation is done by taking the ratio of sum of predicted traffic of all three signals with the sum of the product of each and every signal predicted traffic and queue.

The aggregated output for neighbouring traffic light is calculated using the equation (1) below.

$$FD = \frac{\{(Q1\times PT1)+(Q2\times PT2)+(Q3\times PT3)\}}{PT1+PT2+PT3} \quad (1)$$

Where,

Q1, Q2, Q3 are Queue input for traffic light signals 1, 2 and 3.

PT1, PT2, PT3 are Predicted Traffic output for traffic light signals 1, 2 and 3

FD is Fused data.

If the aggregated value is in the range of VS then the signal timing can be changed by -40s so that it denotes only less cars are there in queue can hence need not provide a larger timing for wait in other signals.

If the aggregated value is in this range of S then the signal timing can be changed by -20s, and for those values in the range of M, the signal timing need not be changed can be in usual way of operation.

If the aggregated value is in the range of L then the signal timing can be changed by +20s which provides a longer duration for the traffic to clear and if the system aggregated value is in the range of VL, the signal timing can be changed by +40s.

V. SIMULATION AND RESULTS

The proposed system is simulated using MATLAB. The fuzzy inference system used here is mamdani fuzzy system. Two inputs are given to the system to get the output. The inputs of this system are arrival and queue of cars in the traffic signal. The output obtained is predicted traffic.

A. Scenario 1

In this scenario, the sensor nodes collect the details regarding the number of cars in queue and arrival and sends it to LCN. The collected data is then used for predicting the traffic. The predicted traffic of different sensor nodes and the number of cars in queue is used for calculating the aggregated value of one traffic signal. Since this aggregated output value lies in the range of M (19-27) there will be no time change in the traffic light signal.

Table II. Sample Data 1

SENSOR NODES	VEHICLES		PREDICTED TRAFFIC
	ARRIVAL	QUEUE	
SN1	20	5	14
SN2	35	10	23
LCN1	19	40	32
PREDICTED TRAFFIC SN1	**PREDICTED TRAFFIC SN2**	**PREDICTED TRAFFIC LCN1**	**AGGREGATED OUTPUT**
14	23	32	23

B. Scenario 2

Like scenario 1, this scenario also collect the details regarding the number of cars in queue and arrival and sends it to LCN by the sensor node. Also the collected data is used for predicting the traffic output. The predicted traffic of different sensor nodes and the number of cars in queue is used for calculating the aggregated value of one traffic signal. Since this aggregated output value lies in the range of L (28-36) there will be increment in time of 20seconds.

Similarly this aggregation formula can be used to determine the aggregated output for all the signals so that traffic congestion can be reduced efficiently.

Table III. Sample Data 2

SENSOR NODES	VEHICLES		PREDICTED TRAFFIC
	ARRIVAL	QUEUE	
SN3	35	40	41
SN4	10	40	23
LCN2	40	22	32
PREDICTED TRAFFIC SN3	**PREDICTED TRAFFIC SN4**	**PREDICTED TRAFFIC LCN2**	**AGGREGATED OUTPUT**
41	23	32	34

VI. CONCLUSION

The paper has shown that a sensor based fuzzy logic model has the potential of eliminating the road traffic congestion to barest minimum. This was achieved by the ability of the fuzzy system to take its own decision by either extending or terminating the timing of a signal. The result shows that it can provide a better way of traffic controller since decisions are not only made by the fuzzy logic but also the cognitive node which has the ability to perform intelligent systems. The experimentation proved that this system solved most of the problems observed in conventional traffic regions and proposed a control system as the flow density was varied according to traffic situations. The simulation result showed that the system maintains an even traffic and can be used during peak hours of a region.

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