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Design and Simulation of a Novel Fuzzy Logic Controller for the Urban Traffic Junctions

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***Abstract*— One of the major problems pertaining in any metropolitan cities of India is Traffic congestion at road intersections. Therefore, it is necessary to address this predicament with an efficient traffic management system. Intelligent traffic control systems are required to consider the problem of traffic dynamically to reduce traffic congestion, pollution and transit time of vehicles at the intersection. This paper describes the design of an intelligent traffic control system based on Fuzzy Logic for a four Road intersection and a novel approach to model and simulate Traffic in MATLAB is illustrated. Fuzzy logic deals with reasoning that is rather approximate than fixed or exact, similar to the way a human brain would address the same problem. Here Fuzzy logic models are developed using Fuzzy logic toolbox in MATLAB. The results obtained show an improvement of 48.49% in the overall outcome of traffic management presented as compared to the conventional traffic controller, marking the current model feasible and realistic.**

Keywords*— Fuzzy logic Controller; Traffic Modeling Algorithm; Intelligent Traffic Management System; Conventional Fixed Time Traffic Controller; Fuzzy rules

I. Introduction

Traffic is a major problem in the city that affects many people. Traffic phenomenon causes many social problems such as stress, Air pollution, excessive fuel consumption, waste of time and etc [1]. Today many researches in the field of artificial intelligence techniques have been performed to improve traffic flow and safety for transportation [2] [3]. Such as expert systems and fuzzy logic system and different algorithms for traffic management have been studied in several papers [4]. In this research, fuzzy logic is used to design the traffic control system. Fuzzy inference enables the system to decide similar to expert human. So traffic control system can make the best decision for the smooth flow of traffic at intersections so that vehicles can cross the intersection with the least possible time.

One of the prerequisites of traffic control and management involve the use of traffic signals. The main goal is to improve the traffic safety at the intersection, maximizing the capacity at the intersection and minimizing the delays. Another goal is to avoid the requirement of the traffic police officer in every junction all the time. On a larger scale, the effectiveness of traffic flow yields a number of economic and environmental benefits. The conventional traffic controller comprises of a constant cycle for the signal operation and the output is indicated in red, yellow or green colors. A lot of advancements have been made in the traffic light control systems. Such as set-ups function according to the 'time-of-day' principle. Further research and knowledge of the applications of modern traffic controllers state that the vehicle-actuated controllers operate with an improved workability [5] [6]. Here, the length of the green phase is adjusted according to the traffic flow and the decision making is carried out by the controller itself. Today, vehicle-actuated controllers are gaining more popularity as they hold a supreme capability of managing traffic flow on real-time basis.

In this paper a 4 traffic signals are set in a 4 road-junction configuration as shown in Figure 1.

Fig.1. A 4 road-junction that has been considered for developing traffic mode

II. Motivation

Transport plays a significant role in the social and economic development. The effectiveness of the role played by transport is to a large extent dictated by the soundness of transport policy and the strategies utilized in implementing the policy. The applications of Intelligent Transport System ITS technologies that have been developed, tried and tested in first world environments and selectively applied in emerging economies, do significantly improve the efficiency and effectiveness of traffic management and road safety [3].

Investments in traffic management systems have proven high returns. Traffic is a major problem in the city that affects many people. Traffic phenomenon causes many social problems such as stress, Air pollution, excessive fuel consumption, waste of time and etc [1].

Today many researches in the field of artificial intelligence techniques have been performed to improve traffic flow and safety for transportation.

III. Objectives

Intelligent traffic control systems are designed after considering various different parameters. The most important parameters that we have considered to improve the traffic status in metropolitan cities of India are:

a. Waiting period delays at traffic signals.
b. Congestion at intersections and junctions.

The following objectives are set with regard to the above parameters:

a. Allot appropriate amount of green signal time for every road based on the traffic density on that particular road.
b. Alert the traffic police officer if the density does not change even after the green signal is given to that particular road, implying that there has been an accident or an event causing congestion of traffic.
c. Development of a model to simulate traffic in software to verify the functionality of the fuzzy logic controller and to compare it with the traditional traffic controller.

IV. Fuzzy Logic Controller

Based on the inputs, number of detected vehicles and the traffic flow, the traffic density is determined by calculating the product of the two inputs and is given to the fuzzy controller. The capability of the controller to cater inexact data and produce a unique output for each scenario forms the basis of operation [9] [10].

In order to maximize the depth of input acquisition, three fuzzy membership functions for both inputs have been incorporated. Their relationships have been defined in the form of 'if else' statements in the fuzzy inference system.

A. Rule Base

Parameter	No. Of Vehicles			
Traffic Flow	Variable	LOW	MEDIUM	HIGH
	LOW	T1	T2,P	T3,P
	MEDIUM	T1	T2	T3
	HIGH	T1	T2	T2

Table 1. Fuzzy rule base

The fuzzy inference engine based on the above logic rule determines the time for which that particular road in the 4 road intersection has green light. There is also another parameter, P, which is the case for calling the police. This is required when the number of vehicles is medium to high and the flow is low, it implies that there has been a dispute or accident causing a traffic jam.

Where the values for T1, T2, T3 are as follows:

T1 <= 15 to 30 seconds
T2 <= 30 to 45 seconds
T3 <= 45 to 60 seconds.

B. Membership Functions:

The membership functions for the inputs and the outputs are defined as follows:

1) Input: Number of Vehicles

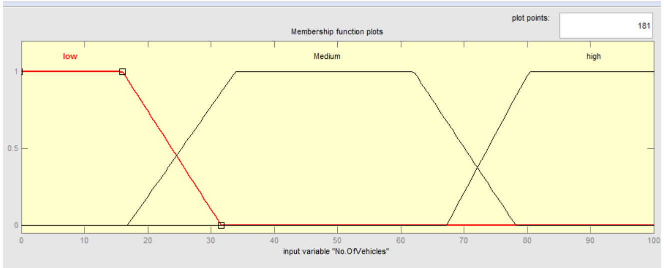

Fig 2. Number of vehicles, membership function with 3 types: Low, Medium and High

2) Input: Traffic Flow

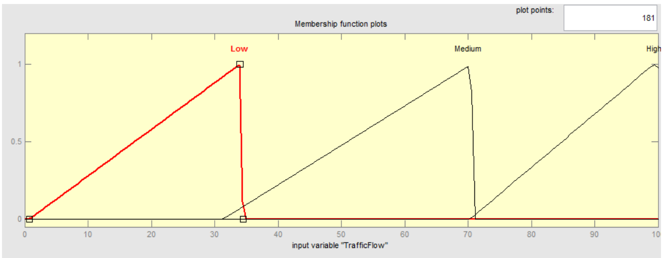

Fig 3. Traffic Flow membership, function with 3 types: Low, Medium and High.

3) Output: Waiting period (Green signal period)

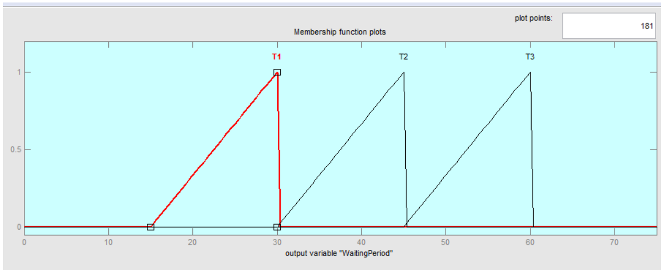

Fig 4. Waiting period (green signal period), membership function with 3 types: T1, T2 and T3.

4) Output: Requirement of police

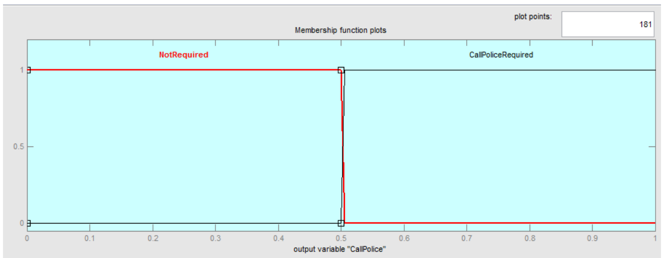

Fig 5. Requirement of police, membership function with 2 types: Required and Not Required

V. Traffic Modeling Algorithm

Traffic in a junction is highly unpredictable. Modeling such a system would require random inputs to accurately define it. Hence a random traffic generator is used; here MATLAB rand function [8] is scaled appropriately to match the traffic input parameters and is used to provide traffic input for each iteration.

The flowchart below shows the steps used to model traffic at a junction. The algorithm assumes that there are already multiple input sources to provide necessary data to the fuzzy logic controller. The fuzzy controller generates the appropriate green signal time for each road. Based on this green signal time the priority for each road is done. In this way the traffic signals effectively provide appropriate green signals to the roads that have a large number of vehicles.

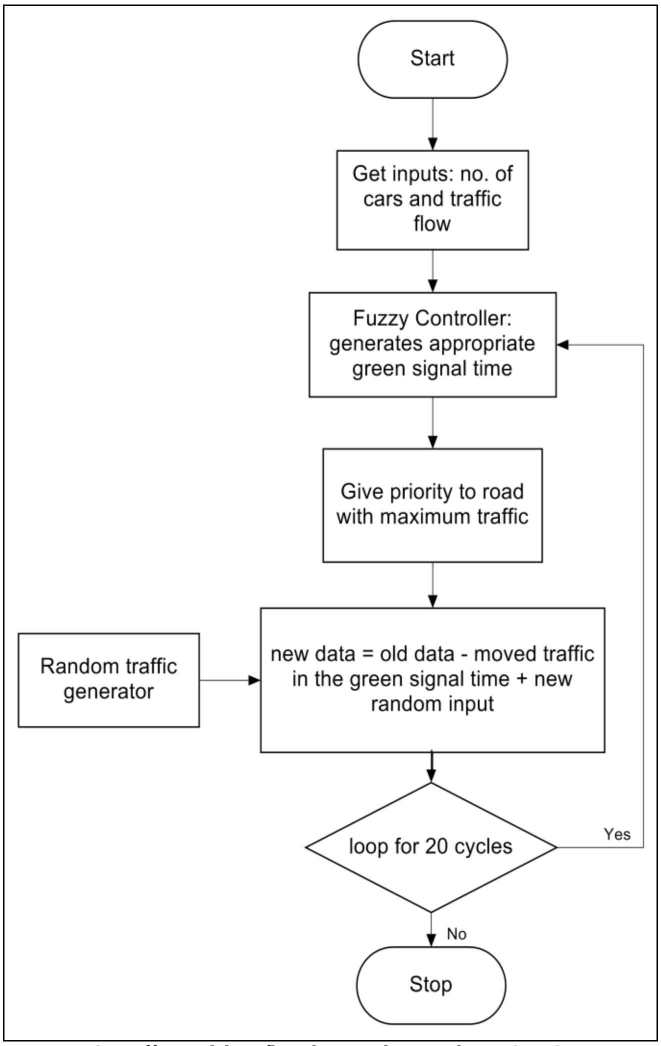

Fig 6. Traffic modeling flowchart implemented in MATLAB

VI. Results:

The results are obtained from the MATLAB implementation of the algorithm shown in Figure 6. The results for the following cases are tabulated in table 2:

Case 1: Low traffic density in all 4 roads
Case 2: High traffic density in one of the 4 roads
Case 3: High traffic density in two of the 4 roads
Case 4: High traffic density in three of the 4 roads
Case 5: High traffic density in all 4 roads

These results are compared to that of standard conventional versions of traffic light operations which usually have pre-defined timing values.

Here the results show that there is an overall improvement of 48.49% in overall performance as compared to the conventional traffic controller, for the same maximum amount of green signal time for each road.

The figures 7 and 8 depict the traffic density variations and the waiting time, i.e., green signal time variations, respectively in each cycle for each road of the junction. They indicate that the fuzzy controller gives priority to the roads with high traffic by allocating large green signal time, and allocate smaller periods of green signal to the roads with lower density.

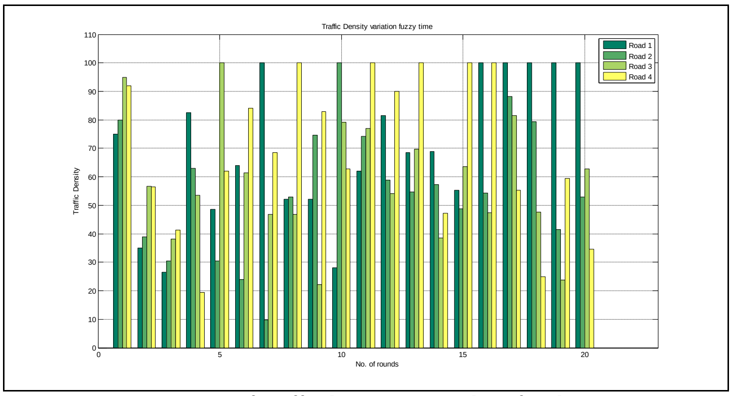

Fig 7. Variation of Traffic density over number of cycles

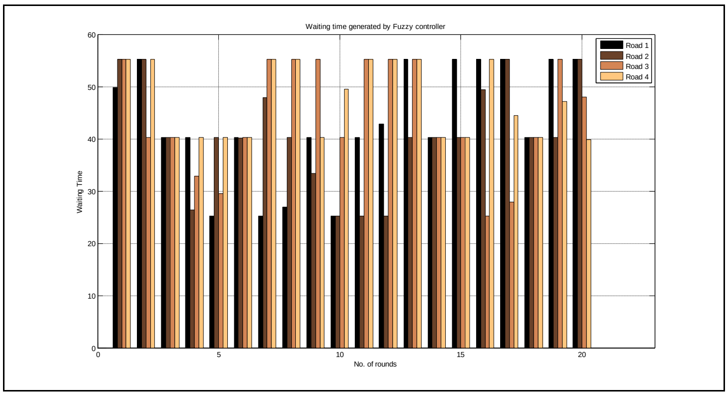

Fig 8. Variation of Waiting period (green signal time) over number of cycles

TABLE II. RESULTS

Cases	Initial Traffic density				Green signal time allorted in 20 cycles Using Fuzzy control signalling in seconds				Total Green signal Time using Fuzzy control in seconds	Total Green Signal Time in Fixed time Signalling each Road in seconds	Time Saved in seconds	Efficiency
	Road 1	Road 2	Road 3	Road 4	Road 1	Road 2	Road 3	Road 4				
1	20	20	20	20	856.1811	907.0936	975.1589	889.8704	3628.304	7200	3571.696	49.607%
2	75	20	15	25	764.1336	917.0404	941.4782	906.9874	3529.6396	7200	3670.36	50.977%
3	80	85	15	20	827.6685	991.3318	881.3766	859.9445	3560.3214	7200	3639.679	50.551%
4	70	80	95	22	921.9653	987.5783	1023.997	896.5224	3830.0637	7200	3369.936	46.805%
5	75	80	90	92	969.5132	972.4579	1063.002	990.5043	3995.4781	7200	3204.522	44.507%
											Average Efficiency	**48.489%**

Table.2 Results tabulated for 5 cases with varying initial traffic density

VII. CONCLUSION

In conclusion, this paper has successfully described a novel method for the urban traffic control, which considers traffic a dynamic problem rather than static. The fuzzy control model has been simulated using an original traffic modeling algorithm and compared with the conventional traffic control system. There was an overall improvement of 48.49% in the Fuzzy traffic control model over the traditional traffic control model. Implying, for duration of 2 hours, with the day's peak traffic, at one junction approximately an hour can be saved.

For future work, the system can also be linked to a database to keep track of the traffic information which is beneficial for security purposes, pedestrian traffic management and air traffic control.

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