

TLCSBFL: A Traffic Lights Control System Based on Fuzzy Logic

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Abstract

Vehicular traveling is increasing throughout the world, particularly in large urban areas. By the increasing use of automobiles in cities, traffic congestion occurs. Thus, there is a requirement for optimizing traffic control methods for better accommodating the increasing demand. Therefore, the transportation system will continue to grow, and intelligent traffic controls have to be employed to face the road traffic congestion's problems. Fuzzy controllers have been widely used in many consumer products and industrial applications successfully over the past two decades. For traffic control, however, fuzzy controllers have not been widely applied. This research presents an application of fuzzy logic for multi-agent based autonomous traffic lights control system using wireless sensors to overcome problems like congestion, accidents, speed, and traffic irregularity. The real time parameters such as traffic density and queue length are obtained by using image-processing techniques. Thus, On and Off timings for the green, red and or amber lights are adjusted to the actual road conditions. Fuzzy logic has been widely used to develop a traffic signal controller because it allows qualitative modeling of complex systems. This paper describes a fuzzy logic signal controller for a four-way intersection suitable for mixed traffic, including a high proportion of motorcycles. The proposed agent-based approach can provide a preferred solution by minimizing the vehicles' waiting time especially the emergency vehicles using fuzzy logic control under the situations that normally occur during emergencies. The effectiveness of this approach is tested by taking two traffic junctions.

Keyword: Traffic lights control system, application of fuzzy logic, autonomous systems, congestion control

1. Introduction

The monitoring and controlling of city traffic is becoming a major problem in many countries. With the ever-increasing number of vehicles on the road, the Traffic Monitoring Authority or the Transport Ministry as the authority is known in some cities has to find new ways or measures for overcoming such problems. The taken measures are development of new roads and flyovers in the middle of the cities; building of several rings such as the inner ring road, middle ring road and outer ring road; introduction of city trains such as the light rapid transit, and monorails; restricting of large vehicles in the

cities during peak hours; and also development of sophisticated traffic monitoring and control systems. Each year, the registration of new vehicles is increased by about twenty per cent. This increment is rather alarming and even with the development of the light rapid transit and new roads, other measures have to be stepped up and be introduced as quickly as possible. The problem of traffic flow during rush hours has somewhat been under the control by city traffic police officers. The movement of traffic in the city was chaotic when traffic police officers were taken off their duties of operating the junctions. It was learnt that Hall wanted to test their automatic traffic control system that had been installed which was still in its initial stage. It is understandable that automatic control systems should relieve humans from manual control; however, such automatic system does not work well in many circumstances especially during oversaturated or unusual load conditions, which could be due to limitations of the algorithms or sensing devices. In this respect, manual control seems to be better due to the intelligence of the traffic police officers in understanding the traffic conditions at the respective junctions. In this paper, we discuss the implementation of an intelligent traffic lights control system using fuzzy logic technology, which has the capability of mimicking human intelligence for controlling traffic lights. Software based on Visual Basic has been developed to simulate an isolated traffic junction. The control of the traffic lights using both conventional fixed-time and fuzzy logic controllers can be simulated in the software. Analysis on the traffic lights simulation such as waiting time, density, cost, etc. can also be made using the software. The software can also be used as an exercise for undergraduate and graduate students to understand the concept of fuzzy logic and its application to a real environment. The rules and membership functions of the fuzzy logic controller can be selected and be changed and their outputs can be compared in terms of several different representations. The software is graphical in nature and runs under the Windows environment.

Fuzzy logic technology allows the implementation of real-life rules similar to the way humans would think. For example, humans would think in the following way to control traffic situation at a certain junction: "if the traffic is heavier on the north or south lanes and the traffic on the west or east lanes is less, then the traffic lights should stay green longer for the north and south lanes". Such rules can now be easily accommodated in the fuzzy logic controller. The beauty of fuzzy logic is that it allows fuzzy terms and conditions such as "heavy," "less," and "longer" to be quantized and understood by the computer.

This paper has been organized as follows. First, a brief overview on traffic lights control system is presented. Then, the development of the software and its usage is next discussed. A comparison between the performance of the fuzzy traffic lights controller and the conventional fixed-time controller is attempted and discussed in the section that follows.

2. Related Work

A significant development of traffic control systems using traffic lights has been achieved since the first traffic controller was installed in London in 1868. Starting from an isolated signalized intersection, the area covered by a traffic control system extended to a series of signalized intersections along an artery ("green wave") out to street networks with several hundred signalized intersections ("area traffic control systems"). The first green wave was realized in Salt Lake City in 1918, and the first area traffic control was introduced in Toronto in 1960. Traffic control equipment has followed technology development. At the very beginning, traffic control had been performed by electromechanical devices. Then, semiconductor-based controllers were introduced, and nowadays microprocessor-based controllers are used in traffic control systems. The development of area's traffic control systems, especially since 1960, has led to introduction of other equipment in traffic control systems, such as computers,

telecommunication devices, vehicle detectors, *etc.* Traffic control strategies have also improved since the installation of the first traffic controller. The strategies can be classified. The most important strategies are as follows:

1- *Fixed-time* strategies: the control (signal plan) is calculated in advance, using statistical data.

2- *Real-time* strategies: The real-time data about traffic processes are used to determine control or its modification.

The first type of control uses a preset cycle time to change the lights. The other type of control combines preset cycle time with proximity sensors, which can activate a change in the cycle time or the lights. The general structure of the present traffic control is shown in Figure 1. The main control measure in urban road networks is the traffic lights at intersections. Traffic lights, besides ensuring the safety of road crossings, may also help in the minimization of the total time spent by all the vehicles in the network, if an optimal control strategy is applied.

Today, the most commonly used technique for traffic light control is based on a micro controller, which controls the four sets of traffic lights at the traffic island/ crossing. This is ordered to work such that the traffic in only those directions, which do not cross each other, is allowed to move at any given time (*i.e.*, green light is displayed in that direction) while in all the other directions, the traffic is forbidden to move (*i.e.*, red light is displayed in that direction). For example, in a country following the left hand drive system (*e.g.*, India) the traffic

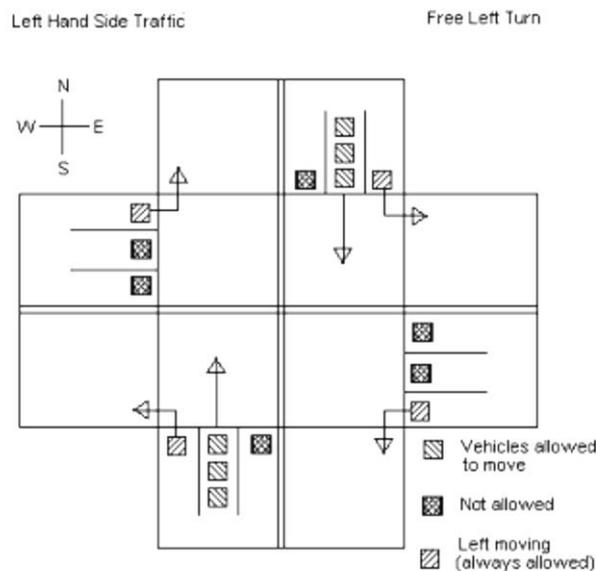


Figure 1. Illustration of Present Day Technique for Control of Traffic Lights

may be allowed to move both from north to south and from south to north, while the east to west direction, the east to north direction, the west to east direction, the west to south direction, the north to west direction and the south to east direction are blocked at that time (as illustrated in the figure).

The timings for the red, green, and amber lights are set such that the traffic moves smoothly in all the directions without people bound in any one of the directions having to wait for an unduly long period for their turn. The turn to move is smoothly rotated until all the sides have a turn before the first side gets a second one. The timings are prefixed according to the normal levels of traffic at that crossing as per the earlier experience.

3. Designed Model

The two junctions have been categorized as J1 and J2 as shown in Figure 2. Wireless sensors S1, S2, and S3 have been used which are installed 500m away from the junctions. We are considering three emergency vehicles, ambulance, police unit, and fire brigade, coming from three different directions at the same time with different speed ratio. Based on their speed detected by the sensors, two actions are performed. One, traffic flow is minimized on their routes so that they can pass by with their maximum possible speed and secondly, their collisions are avoided. In this scenario, first we consider an ambulance coming from the left side of Junction J1 having its route defined straight ahead. It will pass through roadways w1 and w7 with road codes 00001 and 00004, respectively. Secondly, we consider a police vehicle coming towards junction J1 having its route defined and will pass through roadways w3 and w7 having road codes 00002 and 00004, respectively. Finally, we consider a fire brigade vehicle coming from the right side of junction J2 having its route defined and will pass through the road ways w11 and w5 having road codes 00006 and 00003, respectively. Furthermore, the speed of ambulance is detected by the sensor S1, which is 80 km/h, the speed of police vehicle is detected by sensor S2, which is 60 km/h and the speed of fire brigade is detected by sensor S3, which is 40 km/h. Each of these wireless sensors has been installed at 500m away from the junctions. However, the total distance between sensors S1 and S3 is 1.5 km. The expected time of these emergency vehicles are found with the help of the following formula:

$$\text{Distance (s)} = \text{Velocity (v)} / \text{Time (t)} \quad (1)$$

Or,

$$\text{Velocity (v)} = \text{Distance (s)} / \text{Time (t)} \quad (2)$$

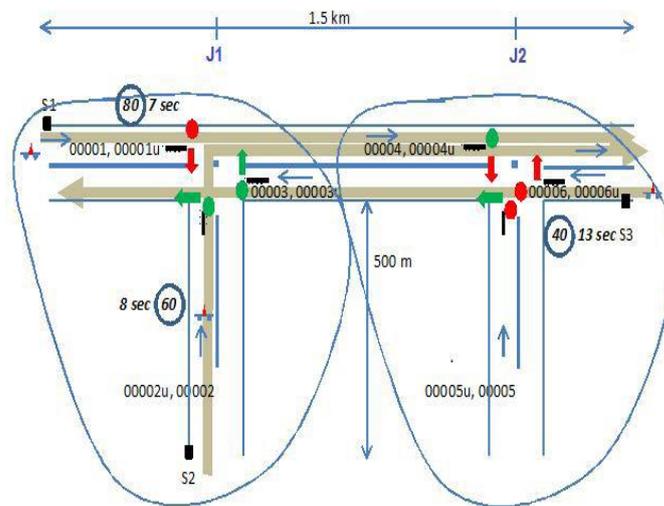


Figure 2. The Proposed Scenario of the Two Junctions

4. Design Algorithm

The data at junction J1 contain sensors, traffic flow, roadways, and traffic light status, which is G for green and R for red are given in Table 1. However, yellow light has been ignored as it is marginal in this case and our focus is on the green light to move the traffic as much as possible during the arrival of emergency vehicles. The data at junction J2 contain sensors, traffic flow, roadways, and traffic light status, which are again G for green and R for red.

Table 1. Data of Junction

Junctions	J1						J2					
Sensors	S ₁		S ₂		S ₃		S ₁		S ₂		S ₃	
Traffic Flow	100		60		95		115		50		80	
Road ways	W ₁	W ₂	W ₃	W ₄	W ₅	W ₆	W ₇	W ₈	W ₉	W ₁₀	W ₁₁	W ₁₂
Traffic Light Status	G	G	R	G	R	R	G	G	R	G	R	R
	G	G	R	G	R	R	G	G	R	G	R	R
	R	R	G	G	G	G	G	G	R	G	R	R
	R	R	G	G	G	G	G	G	R	G	R	R

As each road has been assigned a special code, for U-turn there is ‘u’ written after the code, however, without the term ‘u’ means straight path. In addition, categorization in the form of roadways and road codes has been defined in Table 2.

Table 2. Roadways with Their Respective Road Cods

Road Ways	W ₁	W ₂	W ₃	W ₄	W ₅	W ₆	W ₇	W ₈	W ₉	W ₁₀	W ₁₁	W ₁₂
Road Codes	000 01	0000 1u	000 02	000 02 u	000 03	000 03 u	000 04	000 04 u	000 05	000 05 u	000 06	000 06 u

The code 00001, for instance, contains five digits in which the first digit defines the existence of emergency vehicle. It is ON and OFF primarily. If the code is in the form 00001, it means no emergency vehicle is detected whereas the code 10001 means that we have an emergency vehicle on this route. The second digit defines the existence of ON and OFF traffic light, which is 1 for green and 0 for red. For instance, the code 00001 means traffic light status is red on that route and 01001 means traffic light status is green on that particular route. In case of emergency vehicle coming towards the road, having code 00001 for instance will be of the form 11001, which again indicates the existence of an emergency vehicle on the route, and traffic light signal status, which is green. Upon getting all those relevant data, simulation software MATLAB is used for fuzzy control. Membership functions for both inputs and outputs have been defined in Table 3.

Table 3. Input and Output member Functions

Number of Vehicle	INPUT MEMBER FUNCTIONS	OUTPUT MEMBER FUNCTIONS
0-20	Slow	Very Long
0-40	Below Medium	Long
20-60	Medium Fast	Medium
40-80	Fast	Short
60-100	Very Fast	Very Short

Three inputs in the form of ambulance, police unit, and fire brigade vehicles with their green time as their outputs are shown in Figure 3.

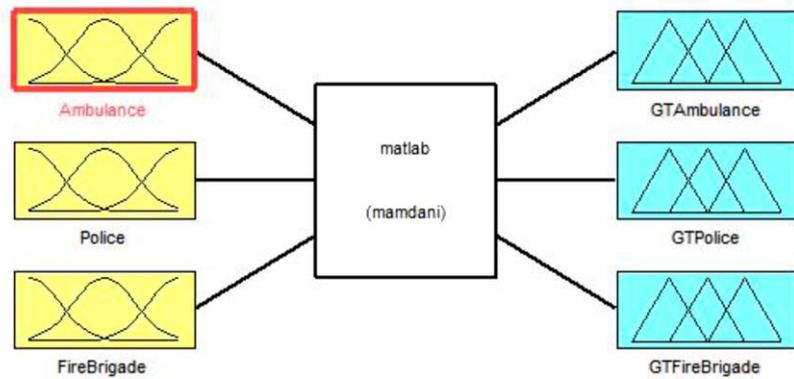


Figure 3. Inputs and Outputs

Five membership functions for each of input and output have been created. Figure 4 shows the membership functions for input variable “Ambulance.”

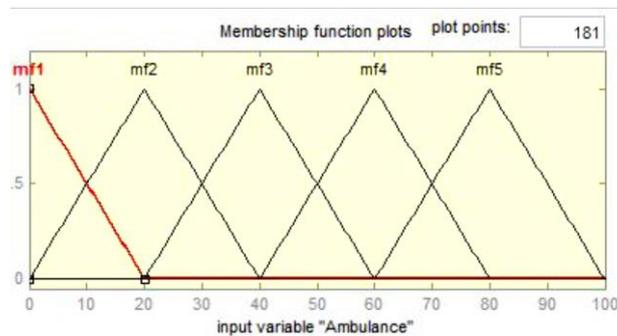


Figure 4. Membership Functions with Their Respective Range

A total 60 rules have been generated. Rules were defined first by considering a single emergency vehicle with all possible speeds. Rules were then defined by considering two emergency vehicles with all possible speeds and finally, rules were defined for three emergency vehicles with all possible speeds. Moreover, by assigning the speed of our inputs, the rule viewer shows the respective green time for our outputs.

5. Simulation

Two surface views has been shown here that indicates the effect of output. Fig. 5 shows a graph between the inputs: Ambulance and Police vehicles and output: Green time for ambulance. Fig. 6 shows a graph between the inputs: Ambulance and Fire brigade vehicles and output: Green time for ambulance.

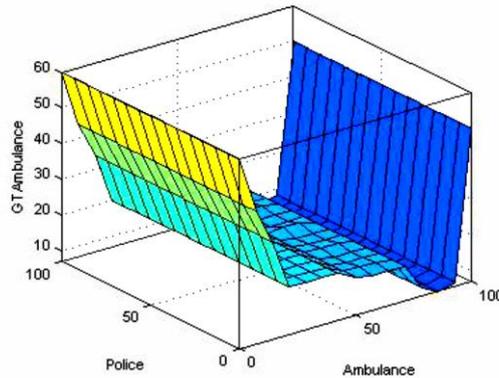


Figure 5. Surface View for Ambulance and Police Vehicles

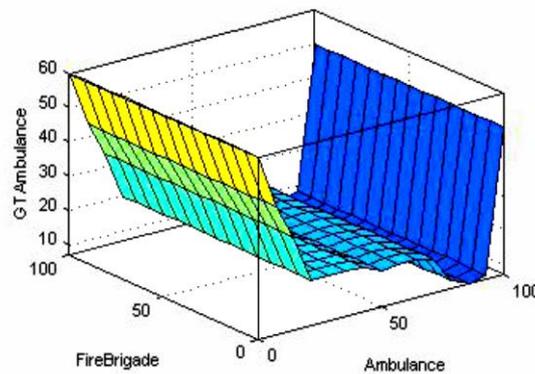


Figure 6. Surface View for Ambulance and Fire Brigade Vehicles

6. Conclusion and Future Works

The system proposed here is very flexible. The feedback of the queue length and traffic densities can be taken from images taken from cameras. Because of the flexibility of the fuzzy logic in dealing with uncertainty, it can be used advantageously for traffic light controlling systems. The proposed fuzzy logic system and fixed time controller produces little difference in results, in terms of constant traffic flow while in the case of time varying traffics, the proposed FLSC is superior to the fixed time controller. This controller gives a suitable green time to improve the traffic capacity effectively and reduces the intersection's delay, which can insure vehicles not to wait too long on the road. While in the case of fixed time controller when green time is finished, this will give the green time to the next phase, even if the current vehicle flow is large. Therefore, arriving vehicles must wait for the next cycle to leave. The performance of the fuzzy logic system is affected by the configuration of the membership functions of the input and output variables and the rule's base. It can be observed that fuzzy logic control system provides a better performance in terms of improving the safety and efficiency by reducing the waiting delay of vehicles on signals. Less traffic congestion and less waiting time at red traffic lights will reduce the fuel consumption, air pollution, sound pollution, and time and energy waste. Furthermore, with the comparative ease terms like weather conditions, environmental aspects etc. can be added to the fuzzy system. A lot of research work has to be done to verify the expected features by simulation. The definitions of the fuzzy sets of the antecedents are also very easily changeable. This is a very promising application of fuzzy logic in practical areas, and will be highly useful in traffic control in the today congestion traffic.

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