Monitoring, Rerouting and Congestion Control of Road Traffic by Fuzzy Logic

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Abstract

With tremendous growth in science and technology the number of vehicles being rolled out every year is in the rise, with every newer vehicle better than its predecessors. This has led to a sharp rise in the number of vehicles being used in the roads by people. Traffic jam is one of the major problems that every country faces. Though it is not possible to totally avert it, it can be alleviated it to a considerable ex-tent by making use of optimized traffic control algorithms. One simple approach is to build an intelligent traffic control and management system that allocates traffic signal time purely based on the traffic density in a road, taking into consideration certain special cases like extreme traffic congestions and passing of ambulances. For example in a junction where four roads meet there might be absolutely no traffic in one road and in other roads there can be moderate to heavy traffic. In that case when round robin scheduling of traffic lights is used some useful time would be wasted in allocating time to the road that has no traffic. Instead by intelligently monitoring the traffic density of each and every road, the total time can be divided between the other 3 lanes and this scheme reduces the average waiting time of vehicles in the road.

Keywords: Fuzzy Logic controller , Defuzzification

1. Indroduction

With a continuous growth in human population, the ve-hicle population is also growing rapidly. Traffic congestion is one of the major problems being faced by people living in all the countries without any parity and has been causing many critical problems and challenges in major cities. Traf-fic congestion has led to a considerable increase in wait-ing time of vehicles at traffic signals, leading to an over-all increase in travel time. This in turn leads to increased fuel expenses and wastage of fossil fuels and also raises many environmental problems like pollution. This paves way for the need for developing an intelligent traffic con-trol and management system using optimised traffic control algorithms that aims to enable free flow of traffic, minimis-ing traffic congestion. Various sensors are being deployed in the road at fixed predetermined distances to determine the traffic density in the road. The software program in the traffic cabinet will allocate traffic flow time based on the traffic density in the road. This system is a learning system that constantly learns from its environment and keeps on up-dating its values for enhancing efficiency and performance. Using this a fuzzy rule base is constructed dynamically with a set of dynamic rules. Having a static set of fuzzy rules has its own drawback as the traffic pattern changes frequently and it is not always accurate. This system which uses a dynamically constructed fuzzy rule base performs better than the former one.

2. Literature Review:

In this system, the traffic flow time is allocated to each of the roads in proportion to the traffic density in the road. Moreover, being a learning system it learns its environment and constantly upgrades the fuzzy rule base and traffic den-sity and traffic flow times and hence it performs efficiently with maximum accuracy. Whereas in Reference paper [4] the signal time is predefined and based on current traffic conditions the green light time may or may not be extended, which does not yield maximum performance always and may not be accurate, as the traffic pattern may change over the days. In this proposed learning system for traffic light scheduling, separate computations are done for weekends and weekdays as the traffic pattern is not same in both cases. This is not taken care in any of the existing systems. More-over in this proposed system there is a provision to detect unexpected traffic congestions if any and also take measures to ease the traffic congestion by alerting the users in the ad-jacent traffic junctions, which is also not present.Moreover passing of ambulances and dignitary vehicles has also been discussed as a special case which reference [1] fails to elab-orate. Clearly the proposed system performs well with a good performance measures than the existing systems.

3. Traffic Density Determination:

In this paper, traffic control and management is done us-ing a fuzzy logic controller. Fuzzy logic technology has the capability to mimic the human intelligence for traffic management and control. It allows the implementation of real life rules similar in which humans would think. Fuzzy logic traffic controller makes use of sensors that counts cars instead of proximity sensors which will only indicate the presence of cars.

3.1. Design:

The design of this intelligent traffic control and manage-ment system assumes that the traffic pattern remains more or less the same, with little variance, for a time span of fif-teen minutes. The sensors deployed in the road would mea-sure the traffic volume first in each of the four roads of a traffic junction in a single stroke and then compute the traffic density of each road.These values are being read by a software program installed in a traffic cabinet that uses a fair algorithm in allocating traffic flow time for each road. The software program determines the ratio of traffic in each of the four roads on a scale of 1 and then divides a static time of four min based on the ratios computed. The four differ-ent values obtained will be the traffic flow times in seconds for each of the four roads of a junction respectively. The traffic density and the traffic flow time of each of the four roads of a junction will be stored in a temporary database along with the traffic ratios. Assume that the traffic ratios are r1,r2,r3,r4 and are in ascending order. Then the fuzzy rule base has an input membership function as traffic ratio which has the following as the possible set of inputs namely 0-r1 , r1-r2 , r2-r3 , r3-r4 and the output membership func-tion as traffic flow time in seconds which is the correspond-ing traffic flow time values of the roads computed by the software program. Thus a fuzzy rule base has been con-structed dynamically. Now using this rule base ,traffic flow time is allocated for each of the four roads of a junction during the first cycle .In the second cycle (after 4 min) once again the same process is repeated and the traffic density, traffic ratio, traffic flow time are freshly computed by the program and is stored in a temporary database. Now the average of the newly computed traffic ratios and traffic density's and the corresponding previous ones present in the rule table is determined and the rule table is updated with the new traffic ratios as inputs and traffic flow times as outputs. This updated rule table is stored in a temporary database. The average of the newly computed traffic flow time and the previous one is determined and this is again stored in a temporary database. Now using this updated rule base table the traffic flow time is allocated for each of the four roads of a junction using traffic ratio as input. The same process which is carried out in the second cycle is repeated in the third and fourth cycle as well and everytime the rule base table and the traffic flow times are updated and stored in a temporary database. At the end of the fourth cycle the the rule base table and the average traffic flow time for each of the four roads are being stored in a permanent database along with the time interval.

Before the fifth cycle starts (ie 20th minute) all values in temporary database are flushed and the above process is repeated for the next four cycles. So for every four cycles a fuzzy rule base table which is approximately accurate is ob-tained and also the average traffic densitys and traffic flow times for each of the four roads of a junction is obtained. So for every hour, four different fuzzy rule base tables are stored in a permanent database along with 4 different traffic densities and traffic flow times for each of the 4 roads. This entire process is carried out for the whole day. This process is carried out every alternate day and the average of all the values of the previous days and current days is de-termined and is updated in the fuzzy rule base table and in the permanent database. The overall working of the system is different during the weekends, which is not the same as the weekdays as the traffic patterns during weekends is dif-ferent from that of weekdays. Hence the traffic flow time allocation for each of the four roads of a junction is differ-ent during weekends. Additionally in order to reduce the computational burden of the system ,the system allocates traffic flow time on a traditional round robin manner during the wee hours of the day ie from 11 PM to 5 AM next day morning. Since traffic is minimal during this point of time in the day its not efficient to carry out the above computations and hence traffic flow time allocation based on round robin scheduling method is adopted. The efficiency of the system is enhanced by using an algorithm that learns and constructs a dynamic fuzzy rule base rather than the static one which it uses later. Therefore the system is resilient. Moreover if necessary the computations can be carried out every alternate month as the traffic pattern for a particular

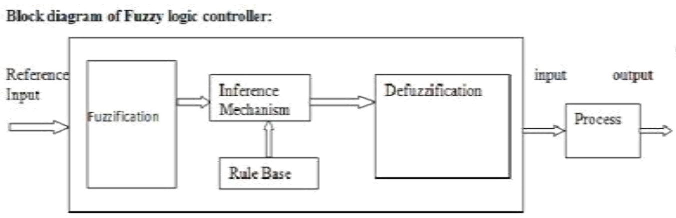

Figure 1

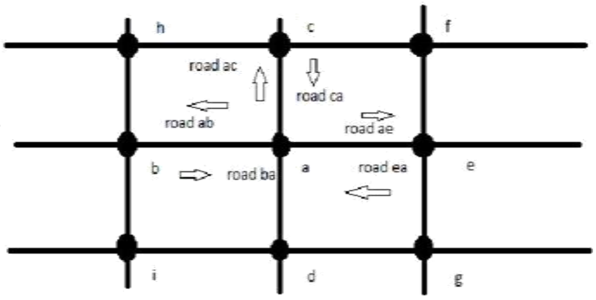

Figure 2

month more or less resembles the previous month and in such a case the rule base already stored in the permanent database can be used. However this is optional depending on the systems performance. Since the system uses round robin scheduling during the wee hours of the day, the over-all performance of the system is maximized and the cost is lowered to a maximum possible extent .

4. Additional Functionalities that improves Performance:

In a traffic junction if there is minimal traffic in all the three roads and if one of the roads has a very high traf-fic density, eventually a large proportion of the entire cycle time ie four minutes will be allocated to the road which is having maximum traffic. This is not desirable, as at certain circumstances it might lead to traffic congestion in other roads in the city. Though the algorithm is based on allo-cating traffic flow time for roads in proportion to their re-spective traffic densitys, as an exceptional case in order to avoid congesting other roads, the algorithm fixes an upper limit on the maximum traffic flow time to be allocated to a road not crossing one hundred and eighty seconds. So if the computed traffic flow time for a road exceeds the above value, the traffic flow time for that road is set to one hun-dred and eighty seconds and the rest sixty seconds is to be divided among the other three roads proportional to their traffic densitys.

Additionally in a traffic junction if there is zero traffic in all the roads except one of them which has a considerable volume of traffic then according to the algorithm the entire cycle time ie four minutes is allocated to a single road. In-variably in most of the cases this is not an optimal solution as the entire four minutes might not be utilised. In this case the algorithm uses formula (1) to determine the traffic flow time required for the vehicles present in the road and to this value an additional overhead of ten seconds is being added. The final value obtained would be the green signal time al-located to that road instead of four minutes which might not be required in most of the cases. In this case the end of this time slice marks the end of the current cycle and next cycle starts automatically, without needing to wait for the entire four minutes to get over in order to start a new cycle. This helps in optimising and reducing idle time to a great extent, in line with the objective.

The average traffic density of a particular road for every four cycle is stored in a database. If the instantaneous traffic density at the road computed by the system at a particular point of time during the day is greater than twice the average expected traffic density at that road during that particular point of time in the day which is already being stored in a database, the system identifies that a traffic congestion has occurred in that road.

Each traffic cabinet maintains a table in the database that has the information about its four nearest adjacent traffic cabinets. As per figure 2, traffic cabinet a has a table in a database that has information about adjacent traffic cabinets b , c, e and d respectively. The table has the following fields (signal-id ,status) where signal-id is used to uniquely identify and distinguish a traffic cabinet just like a primary key and status takes binary values either 0 or 1. Thus each and every traffic cabinet has just four entries in its table stored in the database. When traffic congestion has been detected in a road by applying the above discussed approach, the traffic signal will communicate this to the nearest adjacent traffic signal to which the other end of the road, which has been congested is connected to and sets the status as 1 in the sta-tus field of the table against its name, which is a way of indi-cating that the congestion has occurred. The adjacent traffic signal changes the algorithm by which it functions, such that it will not allocate green signal time for vehicles in the other three roads that wishes to proceed to the congested road. This is a congestion prevention strategy adopted by the adjacent traffic signal in order to avoid further congestion of the already congested road. This strategy is adopted until congestion is prevalent. However, once the instantaneous traffic density falls below the expected traffic density in the road, the traffic signal immediately signals the adjacent traffic signal that congestion has been alleviated by setting the status field against its signal-id back to zero. Once when this happens the adjacent signal starts function-ing normally and continues to route traffic to the previously congested road also. Thereby when congestion is being detected the working of the adjacent traffic cabinets are being altered in order to prevent and ease congestion. In the case of congestion rule 1 is also being implemented. For instance, according to figure 2 when traffic signal e detects that road ae has been congested it communicates to traffic signal a that congestion has occurred. Traffic signal a main-tains the status of its adjacent signals including e in a table. The status-id field of the signal e is being set to 1 by traffic signal a that maintains the table. Thus the traffic signal a adopts a strategy by which it would not route traffic to road ae until congestion has been cleared, which is indicated by setting of the status field back to 0 in the table.

Another important issue which needs to be addressed is the passing of ambulances and vehicles of dignitaries. In such cases the above system is slightly altered, as the same cant be implemented. These vehicles are fitted with RFID tags and when they are detected to be present within the range of a traffic signal cabinet, the software immediately pauses all its currently running process and opens the traffic for these vehicles and resumes back to its normal routine only when these vehicles go out of range. It is similar to the working of interrupts in an operating system.

5. Input and Output Membership Functions and Rule Base:

Input : TR :Traffic ratios (0-r1 , r1-r1+r2 , r1+r2- r1+r2+r3 , r1+r2+r3 - 1)

Output : TFT :Traffic flow time in seconds (computed dynamically)

The fuzzy rule base is set of fuzzy rules. It maps the fuzzy input (Traffic Ratio - input variable) to the corresponding fuzzy output(Traffic Flow time-output variable). In this paper TR stands for Traffic Ratio and TFT stands for Traffic Flow time.

6. Inference Engine and Defuzzification:

Membership functions are used to re translate the fuzzy output into a crisp value. This method is known as defuzzification. The fuzzy inference evaluates the control rules stored in the fuzzy rule base. Defuzzification is a process to convert the fuzzy output values of a fuzzy inference to real crisp values.

7. Results and Performance :

$$t = \frac{n * x}{d * c} \qquad (1)$$

t = total time taken for the traffic to clear i.e get past the signal in seconds

n = number of vehicles in the road

x = average space occupied by a vehicle in square metres d = width of the road in metre

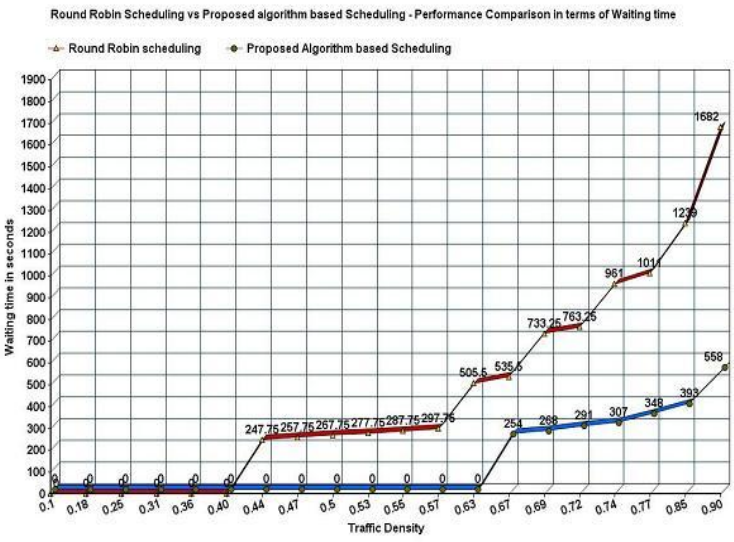

Figure 3

c=average speed of vehicles in metres/second

By fixing constant values for x , d and c and by varying n, we obtain different traffic densitys and correspondingly different waiting times . This is done for both round robin scheduling and proposed scheduling method and results are obtained.

A graph has been plotted between waiting time and traffic density by making use of experimental results obtained. From the graph it can be clearly deciphered that the average waiting time of vehicles is drastically reduced in this system when compared to the traditional round robin scheduling method. This is found to be true irrespective of the traffic density. Clearly the system is highly efficient and accurate in allocating traffic flow time and performs better than the current systems

8. Summary and conclusion

In this paper Fuzzy logic method for traffic control and management has been discussed. Fuzzy logic method gives the exact count of vehicles and moreover since the rule base is dynamically constructed the system is highly efficient in computing the traffic flow time correctly and in easing traffic congestion, than systems that employ static fuzzy rule base. Results clearly indicate that the waiting time of vehicles is considerably reduced when this system is employed than the round robin scheduling method. Hence its performance is better comparatively. But it is expensive as it re-quires sensors to work with. It also has a greater space complexity due to the usage of a database to store all the computed values. It clearly has an upper edge over image processing techniques as the latter fails to work during night. This technique mimics how the human brain would think in a real life situation and produces excellent results

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