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KNOWLEDGE BASED TRAFFIC CONTROL METHOD FOR GUIDING THE MULTIPLE INTERSECTIONS AT URBAN TRAFFIC NETWORK

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Abstract:Intelligent transportation systems (ITS) received great attention in research field as advanced control technology in automation of traffic network. In the present era, it is difficult to control the urban traffic flow efficiently by using traditional methods because of complexity and uncertainties. Hence, the requirement of expert system is needed, which is able to overcome the shortcoming in traditional system and widely applicable in real life including ITS. This paper presents a traffic network model for multiple intersections and traffic control method based on expert knowledge for guiding the traffic flow to proposed architecture. For experimental analysis, the traffic system is simulated with MATLAB simulation tool and illustrate that the proposed controlling method can guide the traffic flow more precisely and accurately.

Key Words: *Expert Systems, ITS, Fuzzy logic, Traffic flow, Multiple intersections;*

1. INTRODUCTION

Traffic network infrastructure is growing but the traffic population is growing at a much faster rate which is the main cause of traffic related problem. One of them is traffic congestion problem affecting the social and economic infrastructure of any country. Theinfrastructure of roadnetwork cannot be expanded with the increasing number of vehicle on the road due to lack of free space.With recent advances in computer and networking technologies, new intelligent and expert solution has been developed that make efficient use of existing road infrastructure, reduce the travel times, andreduce the chances of congestion.Due to dynamicity of road network and sharp increase of traffic congestion, accidents, states, in urban area, the traffic control mechanism becomes more challenging research area. So, the control of traffic flow at multiple intersections with proper guidance is becoming crucial because such control affects the efficacy of urban traffic network.

The traditional fixed-time traffic control method is the most common and popular existing one method in this aspect. These methods use historical traffic patterns and include fixed-time control, and area

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static control, which makes it time consuming and complex.Further, it is well famed, that the traffic system is vigorous in nature, with great alteration in real-time; so the static control rigorously adjusts to the diversity in traffic conditions. Many researchers worked on it, and presented the methods based on expert systems which included the dynamic traffic conditions. But it limited to single intersection and isolated intersection. Therefore, the aim of this paper is to incorporate this approach in multiple intersections which is well suited in urban traffic network.

Rest of the paper is organized as follows: Section 2 described the literature work in brief. The multiple intersection architecture is discussed in Section 3. In Section 4 the traffic control methodfor guiding the network traffic isproposed.Section 5 is illustrated the simulation result for experimental analysis. Finally the conclusion is presented in Section 6.

2. RELATED WORK

The area of traffic flow control has been popular among researchers for over two decades, and a numerous of methods have been proposed by them. With rapid advancement of computer and networking technology, the artificial intelligence techniques have become a substantial and populartechnique for traffic operation. There are variousknowledge-based approaches used to accomplish the flows of traffic at intersections [1] such as: evolutionary algorithms, fuzzy logic, fuzzy-neural network, reinforcement learning. Fuzzy logic based on expert knowledge is commonly used traffic control approach. Variety of methods has been proposed based on fuzzy logic to dealtraffic flow control at signalized intersection. A simulation for an isolated traffic signal control intersection is presented in [2].In this paper the fuzzy controller was designed that worked on two levels. The upper level worked on traffic conditions and the lower level towards green light cycle time.Further the fuzzy logic controller suitable forover-saturated and isolated intersections whilespecial events occur was developed [3]. The decision making method is based on a set of fuzzy rules which take traffic conditions into considerations and the current with next phases. A new fuzzy traffic controller was developed to control traffic flows under both normal and exceptional traffic conditions[4]. A novel fuzzy traffic control method for a single intersection at urban traffic network which control the timings traffic light and phase sequence in exceptional traffic cases, such as road accidents, roadblocks was proposed [5]. An adaptive fuzzy logic controller for a single four-method intersection appropriate for mixed traffic was described in [6]. A fuzzy logic control method for compound junction was describedin [7]. It communicate with neighbour junctions and adaptively manages phase sequences and phase lengths.Atraffic control procedure based onknowledge based for signalized intersection has proposed in [8]. These systems extend or terminate the green signal based on current traffic condition. On the basis of information received from its traffic detectors of isolated signalized intersection, the designed controller confers optimal signals to adjust the phase lengths to the current traffic conditions. A fuzzy logic system method has proposed in [9], which is used to forecast traffic flow and compare the proposed method with existing methods also. Fuzzy Neural Network models (FNNM) was designed for predicting the traffic flow in real time [10]. In this model, the fuzzy logic combined with neural network.In [11] the road network expressed as a matrix form and classified its element. Further, short-term prediction algorithm presented for traffic flow rate based on the urban traffic network model. An artificial intelligence algorithm has been introduced in [12] to enable the traffic management systems' learning ability.In [13] a hybrid algorithm based on Fuzzy Logic Controller and combined with Genetic algorithms, which defined an intelligent traffic signal system. A Hierarchical fuzzy rule-based system was developed and optimized by GA to predict the traffic congestion in [14]. Further, this method is incorporated with cross-entropy (CE) method in [15] and used in traffic prediction.

3. MULTIPLE INTERSECTION MODEL

3.1 Basic element of road element

In order to describe the multiple intersection architecture of an urban traffic network, firstly we define the basic network elements and the relation among these elements [11]. For example, figure 1 illustrates the four adjacent elements with their coordinate position.Here i, j represents the coordinate points, coordinates point i characterise the row number and j represent column number. Figure. 1 shows two vertical neighbouring elements $N(i,j)$ and $N(i+1,j)$both of which are passing. A vehicle in these links can turn left, turn right, or go through, according to a turning rate. For instance, the element $N(i,j)$has four links, and a vehicle is moving on the south link$N_S(i,j)$. When the vehicle turns right on the intersection, it will be on the link $N_E(i,j)$.Link $N_N(i,j)$) and link $N_S(i+1,j)$imply the same road, which joins element $N(i,j)$and $N(i+1,j)$but inverse direction.

Based on the road network elements discussed above, the urban traffic network model can be designed as shown in figure 2. In real traffic, roads network connected to each other and frame like a grid. The grid consist two primarycomponents: joint and link [11]. Links are made up of 2 or more lane, but always two directions, whereas joints can be organised according to the number of links running in. The joint nodes incorporate the T -shape which conjoins 3 links and the Cross which conjoins 4 links. In the figure 2 there are 5 T –shape link and 5 cross link. This network can be represented in the form of matrix as described in [11]. The number of row in this matrix is equal to the maximum number of joint on vertical path whereas the maximum number of joint on horizontal path forms the column in matrix. In the figure 2 there are 4 horizontal and 3 vertical paths are connected to each other and form a grid. It will be represented by 4x3 matrix, as the maximum number of joint is 4 on vertical path B and maximum number of joint is 3 on horizontal path D and E.

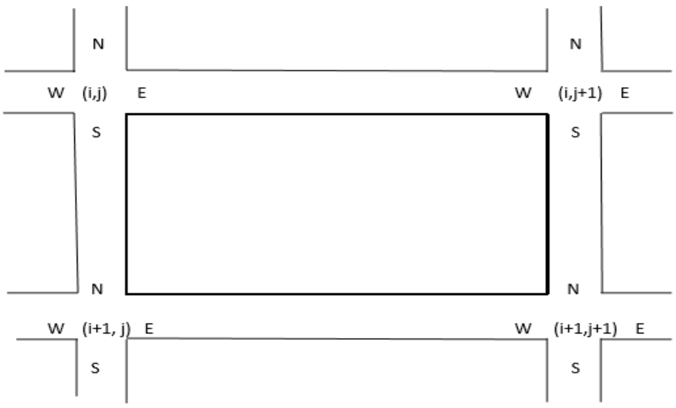


Fig. 1 Four adjacent network element

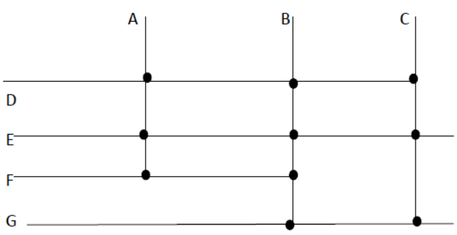


Fig. 2Road network architecture

4. PROPOSED METHOD

The designed traffic control procedure works as an expert system which uses its knowledge in controlling the traffic. The key idea behind this procedure is to authorize an element to belong, more or less strongly, to a class. Consider the expert wish to extend the current green signal by deliberating queue length of vehicles at current green phase, then the class of current green signal having the trait of being extended. If the queue length is too long, the green signal must be extended and support complete association of fuzzy set; in the case of medium queue length, the current green signal may be extended and support partial association and the current green must not be expanded if there is no car in the queue that is queue is empty.

Here two parameters used as an input in this method. The first parameter is the average queue length at green (Q_G) it is the number of vehicles that did not pass the intersection while the signal is in green phase. Anotheris (Q_R) is the average queue length expected at next green.Q_R is the sum of remaining vehicle since last green and number of vehicle arrived while the signal is red; calculated by the following expression:

$$Q_R = R_V + A_V \quad (1)$$

Where,$R_V$is the remainingvehicle that did not pass since the last green signal and $A_V$is the number of vehicles entered while the signal is red. Here,R_V is equal to the number of vehicles that did not cross the intersection while the signal was signal, hence can be expressed as:

$$R_V = Q_G \quad (2)$$

A fuzzy set of 'extend green' by perceiving the average queue length at greencan be entitled as a fuzzy set and the membershipfunction for fuzzy set 'extend green' is characterized in equation (3):

$$\mu_E\ (Q_G) = \begin{cases} 0, if\ Q_G = 0 \\ 0.125, if\ Q_G\,\epsilon(0;8) \\ 1, if\ Q_G\ \geq 8 \end{cases} \quad (3)$$

Next use the fuzzy set of 'terminate green' by characterizing average vehicles queue lengths at a red traffic signal and the membership function for fuzzy set 'terminate green' is entitled in equation (4):

$$\mu_T\ (Q_R) = \begin{cases} 0, if\ Q_R = 0 \\ 0.0625, if\ Q_R\,\epsilon(0;16) \\ 1, if\ Q_R\ \geq 16 \end{cases} \quad (4)$$

There is no standard characteristic function exists to define the fuzzy set; it relies on the problem being fixed and knowledge of individual expert. The controller induce the judgement by conferring the degrees of membership functions of input parameters and theone having highest membership value is chosen as the control action. The action of controller is defined in equation (5).

$$y = \begin{cases} extend, if\ \mu_E(Q_G) \geq \mu_T\ (Q_R) \\ terminate, if\ \mu_E(Q_G) < \mu_T\ (Q_R) \end{cases} \quad (5)$$

On the basis of equation (5) and the current traffic conditions, the system determines whether to extend the current green signal or to terminate it. The current traffic data is accumulated from traffic detectors; then these data are fuzzified in fuzzification process. Fuzzy control algorithm steps described in Algorithm (1) is applied on fuzzified data, which is intends to fuzzy decision process.Further the decision module confers membership grades of traffic conditions and output determines the relevant action that is whether it should remain in the current green phase, or should terminate for next green phase. If the current green phase is in more demand to expand than to terminate, the green signal will be extended. The working of proposed method is depicted in Figure 3.

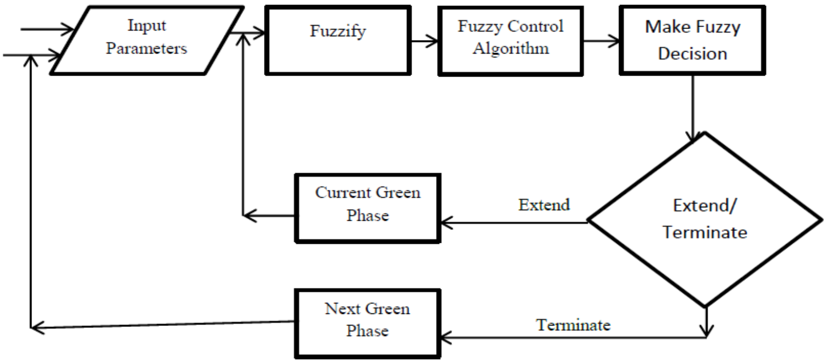


Fig.3 The block diagram of fuzzy control method

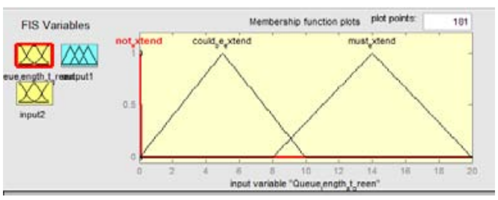
Algorithm 1: FCA (Q_G, Q_R, y)

//***Input***: Queue length Q_G at green and Q_R queue length at next green
//***Output***: fuzzy decision y
Compute μ_E (Q_G)*using equation (3)*
Compute μ_T (Q_R) *using equation (4)*
if $\mu_E(Q_G) \geq \mu_T(Q_R)$
then *extend*
else *terminate*
end if

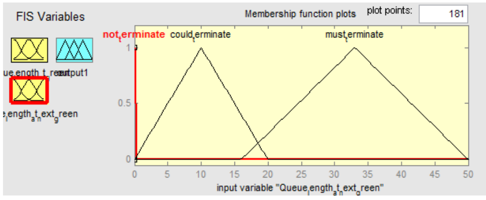
5. SIMULATION RESULTS

The simulation is carried out using MATLAB 2014 and the FuzzyLogicToolbox.TheFuzzylogictoolboxisusefulto define the fuzzy sets and the membership function corresponds to that fuzzy set. This tool quickly and

easily builds the required rules and changes are easily made. This reduces the development time of the simulation model significantly. In this simulation process the minimum and maximum range of input parameters must be set. Here the minimum value set to be zero and the maximum value for queue length at green (Q_G) has been set to 20 whereas for the second input (Q_R), the average queue length expected at next green, the maximum value is set to be 50 as shown in figure 4(a)and (b).



(a)



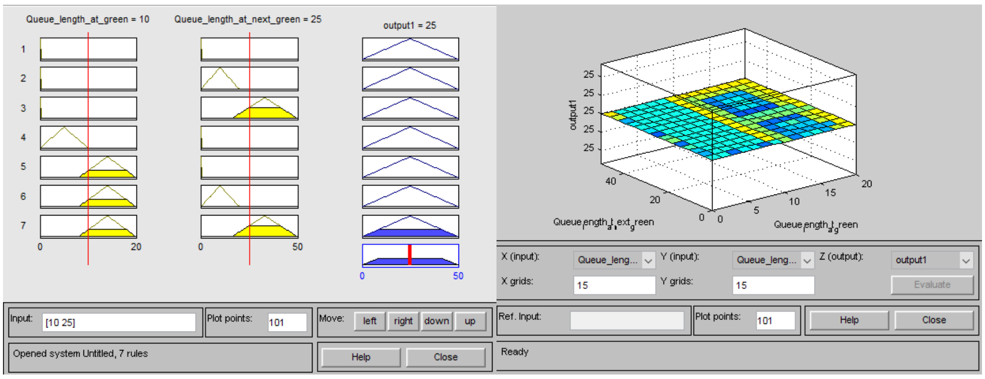
(b)

Fig. 4(a) queue length at green and its membership function (b) queue length at green and its membership function

The proposed traffic control methodwhich is fuzzy logic procedure, afterward green time period, take a decision whether to halt in the current green phase or exchange to the next phase. For example, the parameters of current traffic condition, their membership function and corresponding action is given in table 1.In the similar way, the control action of all possible input parameters which contain the value of queue length at green (Q_G) and the value of queue length at next green (Q_R), can be determined. Based on these parameters the rules have been generated. Figure 5(a) depicts some of generated rule in the simulation and figure 5(b) is 3 dimensional surface view of rules.

Table -1 Experiment Result

(Q_G)	$\mu_E\ (Q_G)$	(Q_R)	$\mu_T\ (Q_R)$	Control action (y)
3	**0.375**	**8**	**0.5**	**Terminate**
4	**0.5**	**8**	**0.5**	**Extend**
5	**0.625**	**8**	**0.5**	**Extend**
3	**0.375**	**4**	**0.25**	**Extend**
4	**0.5**	**4**	**0.25**	**Extend**
5	**0.625**	**4**	**0.25**	**Extend**
3	**0.375**	**10**	**0.625**	**Terminate**
4	**0.5**	**10**	**0.625**	**Terminate**
5	**0.625**	**10**	**0.625**	**Extend**



(a) (b)

Fig.5(a) Rule base (b) 3-D surface view of rules

CONCLUSION

This paper has presented an expert's knowledge to manage and guide the traffic flows at multiple intersection in order to assess the exhibition of the proposed method. The method was tested using

Fuzzy logic tool box on MATLAB 2014. The proposed method has been examinedwith two input parameters. Using different input parameters the membership value has computed. Based on these conditions the rules have generated which represents the control action in different situation. The outputs of the experiments imply that the proposed method can provide competent real-time traffic control at multiple intersections with varying traffic volume level. The simulation result demonstrated that proposed method is improved when traffic volumes are dense. When traffic volumes are light or close to medium, the level of congestion is low and the control method work smoothly produce the same result.The proposed method guide the traffic flow control in efficacy at multiple intersections and may be also influenced by some other micro parameters, such as, accidents, frequency of changing lane, which will be studied further in the future.

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