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A two Stage Fuzzy Logic Adaptive Traffic Signal Control for an Isolated Intersection Based on Real Data using SUMO Simulator

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ABSTRACT
In this paper, a two-stage fuzzy logic system has been proposed to control an isolated intersection adaptively. The aim of this work is to minimize the average waiting time for a different traffic flow rates in real time means. In the first stage, the system consists of two modules named next phase selection module and the green phase extension module. In the second stage the system consists of the decision named module. The study was performed using SUMO traffic simulator. A comparison is made between a fuzzy logic controller and a conventional fixed-time controller. As a result, fuzzy logic controller has shown better performance.

Keywords: *Adaptive traffic control, Fuzzy logic, isolated intersection, SUMO*

INTRODUCTION
Today, the number of vehicles is increasing rapidly and then traffic congestion are a major problem in big cities. In recent years, the management of traffic has become an important part of the modern city. The demand for traffic light control is increased with the rising users and pedestrians on the road. Traffic jams have many negative impacts on the environment, social and economic life, time, production and fuel consumption [1,2]. The high proportion of vehicle-usage, the insufficiency of space to build a new transport infrastructure and a lack of public funds further complicate the problem. In this condition, it is necessary to improve the quality of service for road-users and to provide smart and economical solutions. In a relatively inexpensive way to reduce congestion problems, traffic signal system method was used to ensure the best contingent use of the existing road network. Traffic signaling system strategies are generally divide into three categories; traffic controlled by people, the traditional and sensitive traffic control systems. At the first, the traffic officer uses hand gestures and sometimes verbal communication to control traffic, and in the light of his instinct, decides who must be go or stop. The second way relies on the concept of fixed time, which cannot be changed according to variable traffic demand, so that the times are distributed on different phase of traffic light based on the traffic census [3]. The third way uses sensors such as loop detectors or cameras to calculate and modify signals in real time, the traffic density, speed, flow, queue length and vehicle waiting times are measured immediately on the lanes and stimulate the lights to respond as required.

In this paper, we propose a two-stage traffic signal system at an isolated intersection, using a technique based on fuzzy logic to control traffic signals. In this study, SUMO version 0.32.0 was used to simulate the traffic light. The average waiting time is used to evaluate the performance of the fuzzy logic compared to the fixed time.

Related Works:
Recently, many researchers have focused on finding a new way to control signals that adjusted the timing and phase of the lights to reduce traffic congestions. They present a novel fuzzy model for an isolated signalized intersection, results show that the performance of the proposed model is better that of fixed time control in terms of average waiting time [4]. They developed a logical traffic system that takes into account two-way intersections and is able to adjust changes in traffic signal intervals based on traffic level, the results show that the proposed system provides better performance in terms of total waiting time, total moving time, and vehicle queue [5]. They defines the ATAK system as an traffic management tool at signalized intersections, the results of ATAK showing better performance were compared with the multi-planned traffic control system [6]. The design of an adaptive traffic light controller using fuzzy logic control Sugeno Method is used to determine the length of green time at an intersection and the results show that the traffic light using fuzzy logic control performs better than using fixed time control [7]. They developed algorithms to deal with information uncertainty in dense traffic flows. Adaptive fuzzy logic management was established for traffic control systems, the proposed method allowed it to more effectively control the intersection than the fixed time traffic signals [8]. With proposed WeightSpreadsheetPad technology, the system with fuzzy logic controller and PIC controller for intelligent traffic light improved overall performance compared to traditional traffic control [9]. They proposed a fuzzy logic controller NS-II to control intersection in real-time, the proposed method has a better performance in terms of average total delay time and queue length

compared to type 1, type 2 and type 2-DE [10]. A two stage traffic light system fuzzy logic-based for real-time traffic monitoring has been proposed to dynamically manage both the phase and green time of traffic lights for an isolated signalized intersection, show better performance compared to conventional traffic control in terms of average delay time [2].

FUZZY LOGIC CONTROL SYSTEM

Fuzzy logic traffic light control is an alternative to existing traditional traffic signal control, which can be used for a wide range of traffic arrangements at a road-intersection. General structure of fuzzy traffic lights control system is shown in Fig 1. The lanes is arranged together with the four phases, the first and the second phase have three, the third phase has two and the fourth phase has one lanes. For each lane, a tracker is placed on the road, the detectors are used to indicate the presence and count the vehicles at the same time. This system controls the traffic phases and provides better evaluation of the changing traffic patterns.

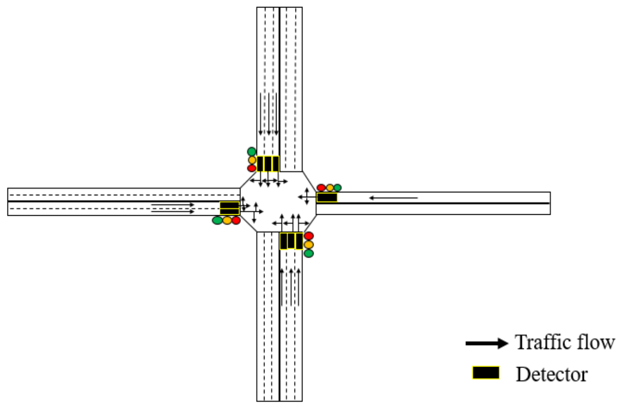

Figure.1. General structure of fuzzy traffic control system

The two-stage traffic light system based fuzzy logic will not only decide whether to extend an existing green phase but also decide which red phase will be set as the green phase and then determine the extension time of the green phase. Therefore, the phase sequence in this system is unclear. Fig 2 shows a schematic diagram of the controller.

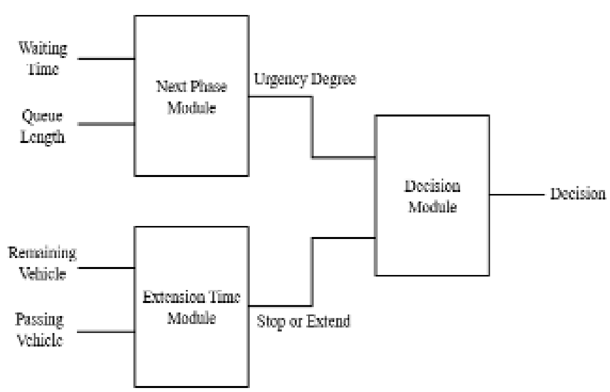

Figure.2. Schematic diagram of the controller

The first stage consists of two modules:

1. Next Phase Module

This module selects a candidate for the next green phase. It observes the traffic conditions of all the red phases except the green phase and selects the most urgent red phase among them. The inputs of this module are the (waiting times and queue length) of all phases except the current green phase, as the output is the degree of urgency for selected phase. The module compares the degree of urgency of all input phases and selects the most urgent. Each input and output has its own membership functions. Inputs have six membership functions (Zero, Very Short, Short, Medium, Long, Very Long) with waiting time and queue length. The output (urgency degree) has five membership functions (Zero, Low, Medium, High, Very High) (see Fig 3).

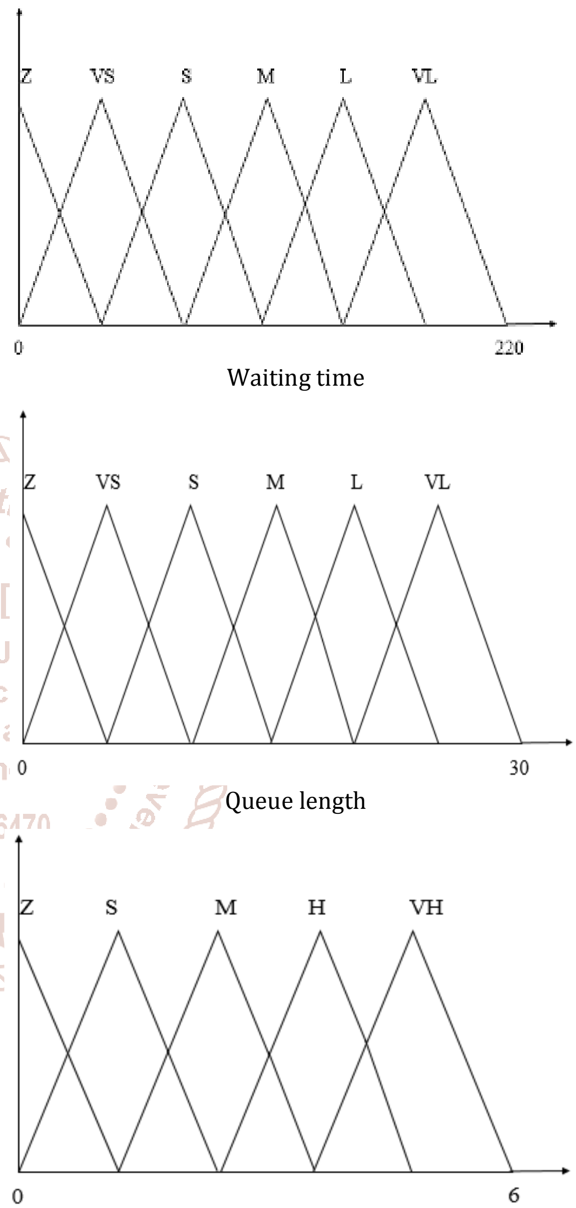

Figure.3.The fuzzy sets of Waiting time, Queue length and Urgency degree

Table I shows a part of the 30 fuzzy rules of this module. For example, if the waiting time is (Zero) and the queue length (Longe) means the Urgency (Medium).

Table I. Some rules of the Next Phase Module.

Rules	Waiting time	Queue Length	Urgency degree
R1	Z	VS	Z
R2	L	M	H
R3	VS	L	M
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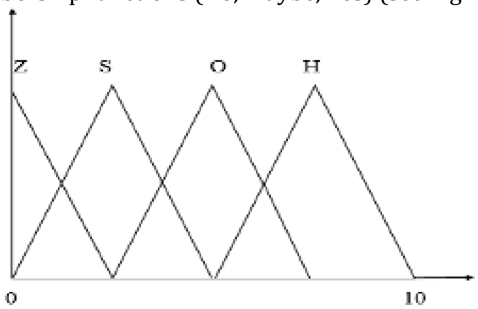
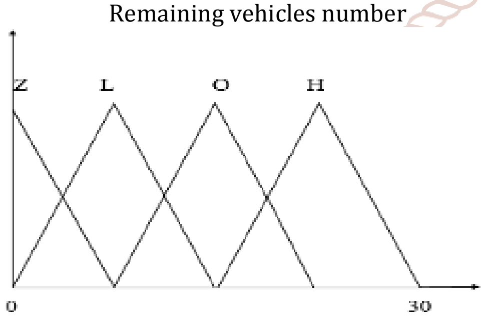
R30	VL	VL	VH

2. Extension time module

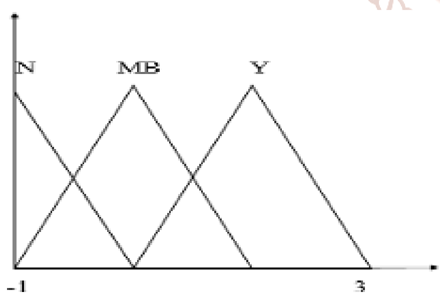
The extension time module observes the traffic conditions of the green phase. Produces the stop degree according to the observation result. The degree of stop indicates that the controller must stop or extend the time of the green phase according to the remaining and passing vehicles number. The inputs of this module are; remaining and passing vehicles number. Output is the stop or extend time of the current green light phase. The current green phase; remaining and passing vehicles numbers have four membership functions. Membership function of the remaining vehicles number (Zero, Short, Medium, Long), membership function of the passing vehicles (Zero, Low, Medium, High). The output of the module (Stop) has three membership functions (No, Maybe, Yes) (see Fig 4).



Remaining vehicles number



Passing vehicles number



Stop or Extend

Figure.4.The fuzzy sets of Remaining, Passing vehicles number and Stop or Extend

Table II shows a part of the 12 fuzzy rules of this module. For example, if the remaining vehicles number is (Short) and the passing vehicles number (High) means Stop or Extend (No).

Table II. Some Rules of Extension Time Module

Rules	Remaining vehicles number	Passing vehicles number	Stop or Extend
R1	Z	M	MB
R2	S	H	N
R3	M	L	N
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R12	L	H	N

Second Stage Decision module

The decision module decides whether to change the green phase or not according to outputs of the first stages. The inputs of the module are the outputs of the first stage (Urgency degree and Stop or Extend). The decision is output and have two membership functions (No,Yes) (see Figure 5).

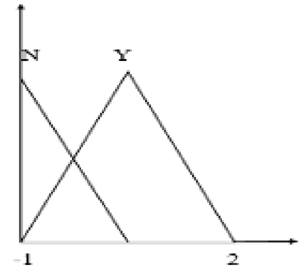

Figure5. The fuzzy sets of decision

Table III shows a part of the 10 fuzzy rules of this module. For example, if the Urgency degree is (Very High) and Stop or Extend (Yes) means the Decision (Yes).

Table III. Some Rules of the Decision Module

Rules	Urgency degree	Stop or Extend	Decision
R1	M	MB	Y
R2	Z	Y	N
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R10	VH	Y	Y

Simulation

In this study SUMO (Simulation of urban mobility) 0.32.0 version is used for simulations. SUMO is a microscopic simulator operating at each vehicle level. To obtain more control over the simulation process, interaction can be established by using SUMO's TraCI protocol during simulation. SUMO is not just a traffic simulator, is an application package that allows the user to import a road network and define the corresponding traffic request.

The data of this study is from heavy traffic congestion real four-way intersection located in urban areas in Kilis (Turkey) obtained in 24 hours by Mosas company (see Fig. 6). The data shows how many vehicles are going from one lane to another every 5 minutes. Using the SUMO program, the cycle time is set to 150 seconds to achieve the lowest average waiting time in the fixed time traffic control system. That is, we give phase1, phase2, phase3, phase4, respectively 25, 40, 18, 55 seconds. In the fuzzy traffic control system, a two-stage three-model traffic light control system was used to achieve the lowest average waiting time. This system adjusts the cycle and phase times according to the traffic conditions based on the data from the detectors. The performance of the fuzzy logic traffic signal controller indicates a 61.363% improvement when compared with the performance of the traditional traffic controller (see Table IV). The isolated intersection was evaluated by simulation.

Fig.6. Kilis intersection

Table IV. Comparison of results

Control methods	Average Vehicle Waiting Time (s)	Improvement
Fixed Time	44	% 61.363
Fuzzy Logic	17	

Conclusion

We proposed the design of a two-stage traffic signal system for the isolated intersection based on fuzzy logic and compared its performance with the simulated traditional traffic control method. Traffic simulation is simulated on SUMO. To control the intersection, the controllers manage traffic signals based on the traffic information they collect. The controller receives information from its detectors. Using this information, the fuzzy rule basic system gave an optimal phase and a signal sequence at the intersection points. The results obtained from the simulation showed that the average vehicle waiting time decreased from 44 seconds to 17 seconds, suggesting that the recommended method was better than the fixed time control method.

Acknowledgment

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