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# *Research on Pedestrian and Vehicle Signal Command System based on Fuzzy control Theory*

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***Abstract:*** This paper mainly studies the timing of intelligent traffic signals.According to the vehicle flow information of the current road phase and the vehicle carrying capacity of the downstream road at the current intersection, the vehicle intelligent decision fuzzy controller is designed.A pedestrian intelligent decision fuzzy controller is designed combining the number of waiting pedestrians and the walking speed of pedestrians.Finally, the system is simulated and the experimental results are analyzed, which can greatly improve the crossing capacity of vehicles and pedestrians.

## 1. Introduction

Intelligent Transport System (ITS) is a comprehensive design of computer network technology, sensing technology, image recognition and artificial intelligence applied to ground traffic management System.ITS provides more reasonable and effective traffic rules and optimizes the relationship between pedestrians, vehicles and roads. At present, many economically developed countries apply ITS to the traffic command system of cities and expressways.Due to the large number of roads in China, the most traditional control method is still adopted to control the traffic lights at many intersections, that is, to control the passage time according to the preset control time. Such design often leads to unreasonable Settings in different time periods.

This paper puts forward a kind of intelligent traffic signal control system design based on fuzzy control, image processing techniques for pedestrians and vehicles for precise detection, real-time traffic information collection and adjacent intersection at the same time [1].

## 2. Relational Research

### 2.1 Current application of intelligent traffic control system

At present, there are two kinds of mainstream intelligent transportation systems abroad, one is SCOOT system in Britain, the other is SCATS system in Australia.SCOOT (Split, Cycle and Offset Optimization Technique) is a kind of real-time traffic signal control system, use traffic data in real time detection, the vehicle detector for continuous detection of road intersection of all import way after the traffic demand, through the traffic demand to optimize the intersection signal timing scheme, the intersection of the vehicle to minimize stops and delay time.SCATS(Sydney Coordinated Adaptive Traffic System), also known as The Sydney Coordinated Adaptive Traffic

System, has some special advantages compared with SCOOT and is popular in developing countries due to its lower investment.

### 2.2 Detect the number of real-time vehicles and pedestrians based on YOLO V4

The main task of target detection is to find out all the objects of interest in the image. In this paper, the objects of interest are pedestrians, motorcycles, bicycles, cars, buses and so on.I have written a paper about this aspect "Detection and Identification of Moving Objects at Busy Traffic Road Based on YOLO V4". Based on YOLO V4 algorithm, this paper identifies and determines the location and number of pedestrians, motorcycles, bicycles and cars, and sets up the collection objects of this data set, and carries out training and testing on the photo set.Through the statistics of the recognition rate, missed detection rate and error rate, the network trained in this paper has high accuracy, and the processing speed can reach about 30FPS, which meets the requirements of real-time[2].

## 3. Principle analysis of fuzzy control theory

Fuzzy Control Theory (Fuzzy Logic Control Theory) is also called Fuzzy Logic Control Theory.Fuzzy control is a kind of nonlinear intelligent control.

Fuzzification is to transform the exact input quantity into the fuzzy quantity, that is, to transform the input quantity into the standard theory domain by using different corresponding relations. This thesis chooses combine the advantages of the maximum membership degree method and gravity method center average method, assuming that the fuzzy reasoning results are composed of N fuzzy set, fuzzy inference results of the maximum membership degree of fuzzy set and centres on average, achieve precise value after center average method, center the calculating formula of average method as shown in formula 1.

$$y* = \frac{\sum_{i=1}^{N}(y_i^* \mu_{max}^i(y))}{\sum_{i=1}^{N} \mu_{max}^i(y)} \quad (1)$$

In this, $y*$ represents the center of the ith fuzzy set, $\mu_{max}^{i}(y)$ represents the maximum membership degree corresponding to the ith fuzzy set.

## 4. Intelligent timing decision research

### 4.1 Traffic signal control analysis

The traffic flow in which the road traffic signal light is displayed in the same color is called a signal phase. For example, the intersection controlled by four phases is selected. The intersection 2, 3, 4 and 5 are adjacent to the central intersection 1, and the traffic flow at intersection 1 will influence the traffic at the adjacent intersection, as shown in Figure1.

Any vehicle passing in any phase will affect the traffic of its downstream section in the future.In this paper, based on the real-time traffic flow information of the phase detection, combined with the vehicle carrying capacity of the downstream section of the phase, as one of the time judgment conditions of the green traffic in this phase, the fuzzy logic control algorithm is used to realize the optimal green traffic time of this phase[4].

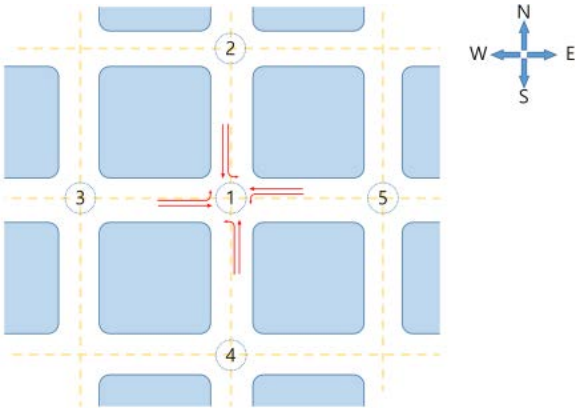


Figure 1 Schematic diagram of intersection

### 4.2 Vehicle timing rules

In the previous paper, real-time traffic flow information was processed based on YOLO V4 target detection method, and real-time vehicle and pedestrian number information was obtained.Due to the mutual influence of vehicles at adjacent intersections, considering the carrying capacity of vehicles at adjacent sections, the green traffic time of vehicles at the intersection should be adjusted appropriately to avoid overcrowding on adjacent sections.

#### 4.2.1 Road vehicle carrying capacity

Take a three-lane road as an example, including left turn lane, straight lane and right turn lane.Since right-turning vehicles can pass, right-turning vehicles are not counted.Cars, busesand freight trucks are the main vehicles in urban areas. The lengths of vehicles of different models are different. The average vehicle length is set as $C_{AL}$, the interval between adjacent vehicles is set as $\Delta C$, and the road length is set as $L$. The maximum number of vehicles $N_{max}$ on the road is calculated by formula 2.

$$N_{max}=\frac{L+\Delta C}{C_{AL}+\Delta C}\times 2 \tag{2}$$

#### 4.2.2 Research on vehicle signal timing based on fuzzy control

The input of the vehicle signal fuzzy controller is the traffic flow information of the current phase and the vehicle carrying capacity of its downstream road.

Taking the through vehicle traveling from south to north as an example, the domain of the number of straight phase vehicles traveling from south to North $N_V$ is$\{0,1,2 \ldots N_m\}$, $N_m$ is the number of saturated vehicles passing through in the longest green light time, set $N_m$=30, and divide it into five fuzzy subsets, recorded as $\{N\_VS, N\_S, N\_M, N\_B, N\_VB\}$, divided vehicles into five levels from less to more; The domain of vehicle carrying capacityof the downstream road $C_V$is$[0,1]$, which is divided into five fuzzy subsets and recorded as $\{C\_VW, C\_W, C\_M, C\_S, C\_VS\}$, divided $C_V$ into five levels from less to more; The green light travel time of the vehicle cannot be too short or too long. Set the universe $T_V$as$[20,80]$and divide it into five fuzzy subsets, which are recorded as$\{T_VS, T_S, T_M, T_L, T_VL\}$, divided the travel time into five levels from less to more[5].

Triangle membership function and trapezoidal function are selected to carry out the fuzzy process of input and output. The membership function is shown in Figure 2.

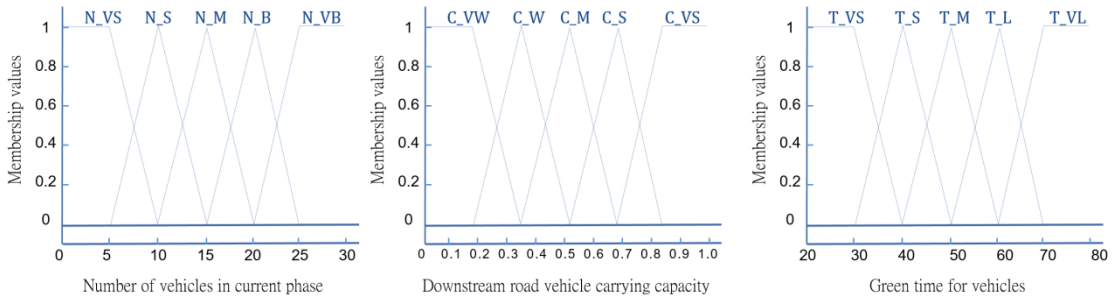


Figure 2Membership function of input and output variables

According to the above membership function, 25 control rules can be formulated for green pass time, and the corresponding rules are shown in Table 1.

Table 1 The rules table of fuzzy control in vehicle transit time

| Cv / Tv / Nv | C_VW | C_W | C_M | C_S | C_VS |
|---|---|---|---|---|---|
| N_VS | T_VS | T_VS | T_VS | T_VS | T_VS |
| N_S | T_VS | T_S | T_S | T_S | T_S |
| N_M | T_S | T_S | T_M | T_M | T_M |
| N_B | T_S | T_M | T_M | T_L | T_L |
| N_VB | T_M | T_M | T_L | T_L | T_VL |

The Mamdani method is used for fuzzy reasoning of green light travel time, and the fuzzy green light travel time is defuzzified by the central average method to obtain the specific green light travel time corresponding to the current phase traffic flow. The green traffic time of vehicles in other phases has the same decision-making principle as that in the straight phase from south to north. The green traffic time of vehicles $T_L$ in the left turn phase is usually less than that in the straight phase $T_V$, and its universe can be set to $[15,60]$.

### 4.3 Pedestrian timing rules

Per lane width of 3.5 meters, one-way lane 3, two-way six lanes road as an example, pedestrians should be through the width of the road for at least 20 meters, the pedestrian walking speed of 1.5 m/s, estimates that pedestrians through the least safe time of the road about 14 seconds, so pedestrians the shortest transit time is less than the shortest straight traffic time, set up to 20 seconds.The speed of pedestrians is inversely proportional to the number of pedestrians.Therefore, according to the two variables of the number of pedestrians in the waiting area and the passing speed, the fuzzy controller can simulate the output of the passing time of pedestrians[6].

The input quantity is the number of pedestrians in the waiting area $N_P$, the universe is set as$[0,40]$, and it is divided into five fuzzy subsets, which are recorded as $\{(N\_VL, N\_L, N\_M, N\_B, N\_VB)\}$; The universe of pedestrian speed $V_P$ is $[1.1,1.7]$, which is divided into five fuzzy subsets, which are recorded as $\{V\_VS, V\_S, V\_M, V\_F, V\_VF\}$; The output is the time $T_P$ required for pedestrians to cross the road, and the universe is set as$[20,80]$. It is divided into five fuzzy subsets, which are recorded as $\{T\_VS, T\_S, T\_M, T\_L, T\_VL\}$. Schematic diagram of membership function are selected for the fuzzification process of input and output, as shown in Figure 3.

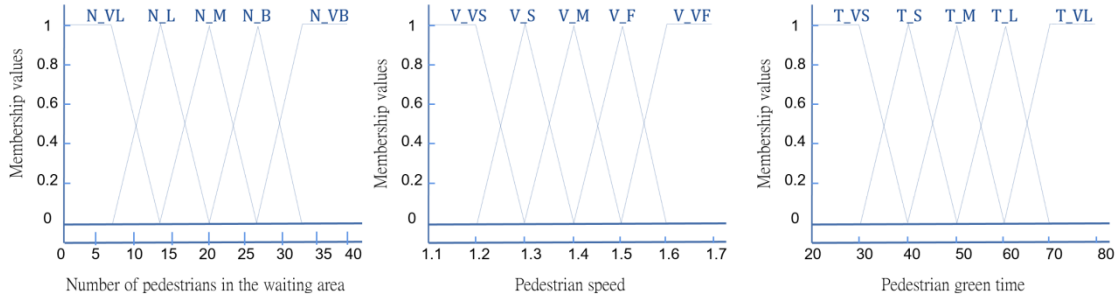


Figure 3 Schematic diagram of membership function

According to the fuzzy subset formulated above, 25 rules can be formulated to control the green pass time of pedestrians, as shown in Table 2.

Table 2 The rules table of fuzzy control in pedestrian transit time

| Np \ Vp | V_VS | V_S | V_M | V_F | V_VF |
|---|---|---|---|---|---|
| N_VL | T_VS | T_S | T_M | T_F | T_VF |
| N_L | T_S | T_S | T_VS | T_VS | T_VS |
| N_M | T_M | T_M | T_S | T_S | T_VS |
| N_B | T_L | T_L | T_M | T_M | T_S |
| N_VB | T_VL | T_L | T_L | T_M | T_M |

In the fuzzy reasoning process, Mamdani method is first used for fuzzy reasoning of pedestrian green light travel time, and then the center average method is used to deconfuzzize the fuzzy pedestrian green light travel time, and the specific pedestrian green light travel time corresponding to the current number of waiting lines is obtained.

## 5. Simulation experiment and result analysis

The algorithm in this paper was simulated and tested on Windows10 operating system computer, which was configured with Intel Core i7-7700 CPU, main frequency 3.6ghz, 8GB memory, and R Language was used as the test environment for algorithm development.

According to the statistics, in a typical single lane, the number of waiting vehicles is usually 5 to 10 at the intersection with small traffic flow, and the passage time is mostly 30 seconds.At the intersection with relatively large traffic flow, the number of waiting vehicles in a single lane is about 10 to 20, and the passage time is about 60 seconds; while on the road near the city center, the road vehicles in a single lane are crowded, and the number of congestion vehicles can reach more than 30, and the passage time is as long as 80 seconds.35 vehicles are selected as the maximum number of waiting vehicles, and the longest green pass time is 80 seconds. Then, the membership function of the fuzzy controller for the vehicle green light duration is shown inFigure4.

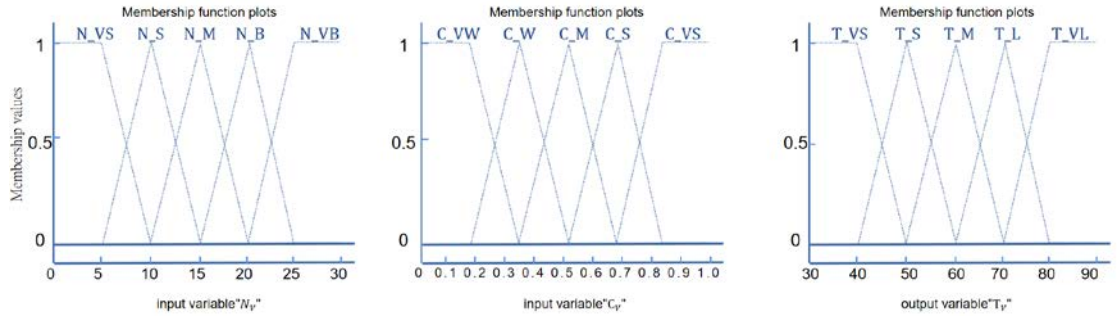


Figure 4 The membership function of the fuzzy controller for the vehicle green light duration

As can be seen from the figure, if there are many vehicles waiting, the green traffic time should be appropriately increased.However, considering that increasing the traffic time will also affect the downstream road traffic, when the downstream road traffic is more crowded, it is necessary to appropriately shorten the current intersection vehicle traffic time.

Table 3 The table of vehicle green time for different parameters

| $N_V$/n / $T_V$/s / $C_V$ | 10 | 15 | 20 | 25 | 30 | 35 |
|---|---|---|---|---|---|---|
| 0.2 | 32 | 42 | 44 | 52 | 52 | 58 |
| 0.5 | 42 | 52 | 52 | 62 | 62 | 65 |
| 0.8 | 42 | 52 | 62 | 72 | 72 | 76 |

Table 3 shows the green output schedule when different parameters are set. It can be seen that the output results are basically consistent with the actual situation.

According to the survey, pedestrian crossing speed due to gender, age, weather and other factors are different, the maximum number of pedestrians waiting is set to 40, the average crossing speed is set to 1.5m/s, the speed range of pedestrian crossing is set to 1.1-1.7m/s, and the crossing time of pedestrian is estimated to be about 30-80 seconds. Then, the membership function of the fuzzy controller for the pedestrian crossing green light duration is shown in Figure 5.

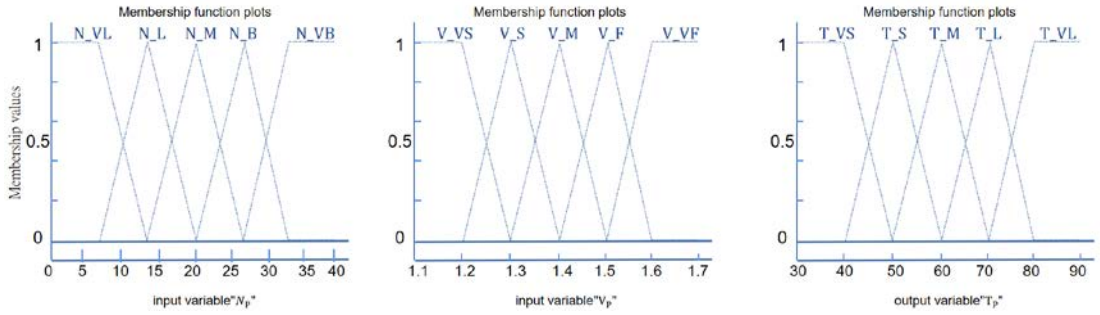


Figure 5 The membership function of the fuzzy controller for the pedestrian crossing green light duration

As can be seen from the figure, as the number of waiting pedestrians increases, the time required for pedestrians to cross the street also increases. Table 4 shows the actual green output schedule of pedestrian fuzzy controller with different number of pedestrians.

Table 4 The table of pedestrian green time for different parameters

| $N_P$/n / $T_V$/s / $V_P$/m/s | 10 | 15 | 20 | 25 | 30 | 35 |
|---|---|---|---|---|---|---|
| 1.2 | 46 | 54 | 62 | 72 | 72 | 73 |
| 1.4 | 35 | 44 | 52 | 58 | 61 | 62 |
| 1.6 | 30 | 32 | 42 | 48 | 56 | 62 |

As can be seen from the above table, the output results are consistent with the actual time required by pedestrians crossing the street.When the number of pedestrians is small, set the pedestrian crossing speed faster;When there are a large number of pedestrians, set the pedestrian crossing speed to be slow.The fuzzy controller can optimize the control time of pedestrian crossing signal and improve traffic efficiency.

## 6. Discussion

In this paper, based on the real-time traffic flow and pedestrian flow information, using the fuzzy control principle to study the intelligent timing algorithm of signal, the green traffic time of vehicles and pedestrians is reasonably allocated. Through the comparison of experimental simulation data,

the fuzzy control system can complete the dynamic output of green time according to the recognition and counting of vehicles and pedestrians at the intersection. Using this system can improve the efficiency of vehicles and pedestrians, reduce the invalid waiting time of signal lights and the number of vehicle stops, and at the same time can meet the pedestrian priority.

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