Fuzzy Control System For Controlling Traffic Lights

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***Abstract*—This paper introduces a flexible technique for the control of traffic lights using fuzzy Mamdani type controller. The real time feedback parameters, traffic density, and queue length are obtained using image processing techniques *viz.* partitioning and segmentation. The on and off timings for green, red and amber lights are adjusted as per the actual road conditions. The defuzzification of the combined results is done using Height method.**

***Index Terms*—Fuzzy control, Visual Feedback, Image segmentation, Real Time application**

I. Introduction

Today, we are living in the world of automation. Micro controllers control most things around us. The control of traffic lights is a well-known area where this type of control system is incorporated. But, the control is not flexible, based on the condition of traffic at the crossing. Rather, the on and off time periods are fixed for the red, green and amber lights. At most, these durations are varied as per the time of the day, the day of the week etc. There is no real-time adjustment of the on/off times as per the traffic conditions on the crossing. This paper proposes a method for introducing more flexibility in the control of traffic lights using visual feedback from images acquired by cameras, image segmentation and fuzzy control techniques.

II. THE PRESENT DAY TECHNIQUE

The usual system is explained with reference to Fig. 1.

The most commonly used technique for traffic light control today 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

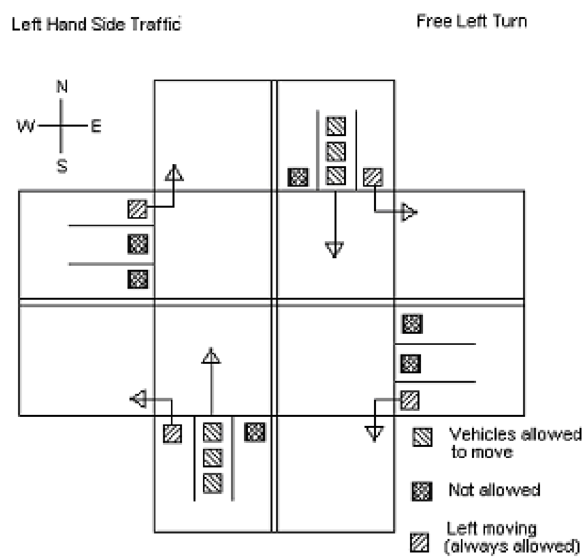

Fig. 1. Illustration of Present Day Technique for Control of Traffic Lights

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 till 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.

III. THE PROPOSED TECHNIQUE

The technique described above is a typical nonflexible control technique. The technique being proposed in this paper uses the technique that a human (traffic policeman) would employ in the same situation. The human operator can observe the actual condition of traffic and change the timings according to the actual condition of queues and rush in different directions while still maintaining the fair rotation of turns. In contrast a micro controller will keep the light in a direction as ‘green’ till the allotted time span is over, even though there may not be any vehicles waiting in that direction, whereas there may be a long waiting queue in other

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directions. This paper proposes a technique to use this human heuristic to make a real time system for the automated control of traffic lights, which is flexible enough to adjust to the actual levels of traffic in various directions at the crossing.

A. The Heuristic

The Heuristic used is as follows:

- Turn the light green for N-S and S-N direction and red for the others
- Wait for interval T that is not a prefixed one but is decided according to the traffic conditions in the allowed directions. The maximum allowed time for one pair of directions is prefixed (at T_{max}) but can be reduced (By an amount T_{adj}) to decide T_{left} as the traffic in the allowed direction thins down.
- Next the above two steps are repeated for permitting traffic to move in the other three pairs of directions (The N-W & S-E together, The E-W & W-E together and lastly the E-N & W-S directions together.)
- The whole cycle is repeated again from the beginning

B. The Model:

The model being used is the fuzzy Mamdani type controller. [1]

- For each pair of directions (as per the heuristic in 3.1 above), turn on the green lights, start the timer, wait for 1 minute, and apply the following crisp and fuzzy 'If then rules'.
- Set the following values (Initialize; These initial values may be varied as per the conditions at the traffic crossing in question)

T_{max} = 7 minutes
T_{min} = 1 minutes
T_{left} =T_{max}
Timer = Time elapsed = 0.

R1: Crisp Rule:
If (Time elapsed in allowed lane >= T_{min})
Then (Apply Rule 2)
Else (Wait for 1 minute and reapply Rule 1)

Rules 2 to 7 are fuzzy inference rules, summarized in table 1 below [2]. The antecedent fuzzy sets are also shown in Figures 2 and 3. For applying the applicable rules, the matching degree for each rule is found, T_{adj} is inferred for individual rules, and the result is combined and defuzzified, before taking the final decision for finding T_{left} [3].

R2:
If ((Queue length is Long) and (Queue density is heavy))
Then (T_{adj} = 0)

R3:
If ((Queue length is Long) and (Queue density is light))
Then (T_{adj} = 0.2 * T_{left})

R4:
If ((Queue length is Medium) and (Queue density is heavy))
Then (T_{adj} = 0.2 * T_{left})

R5:
If ((Queue length is Medium) and (Queue density is light))
Then (T_{adj} = 0.5 * T_{left})

R6:
If ((Queue length is Short) and (Queue density is heavy))
Then (T_{adj} = 0.5 * T_{left})

R7:
If ((Queue length is Short) and (Queue density is light))
Then (T_{adj} = 0.8 * T_{left})

The rules for finding the values of T_{adj} for various combinations of antecedents are summarized in table 1 below:

TABLE I
RULES FOR CALCULATION OF T_{ADJ} FOR VARIOUS CONDITIONS

Queue Density	Queue length		
	Long	Medium	Short
Heavy	0	0.2 * T_{left}	0.5 * T_{left}
Light	0.2 * T_{left}	0.5 * T_{left}	0.8 * T_{left}

The distributions for traffic density being heavy or light are made as per the density of traffic in the concerned lane, using image processing (mid level) to find the density of that part of the picture.

The queue lengths are classified based on the distance to the end of the queue behind the stop line marked on the road.

The antecedent distributions are as shown in the curves 1n figures 2 and 3 below:

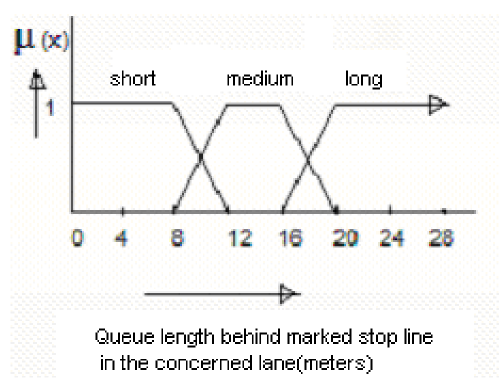

Fig. 2. Antecedent curves for Queue length.

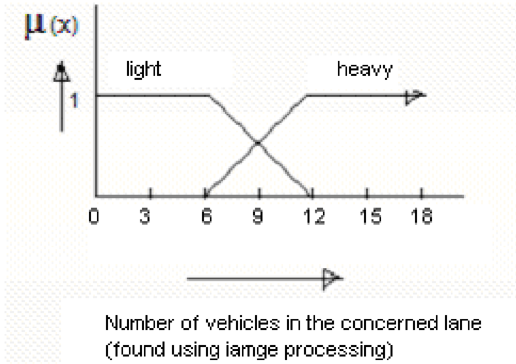

Fig. 3. Antecedent curves for Traffic Density.

The antecedent curves described in Figures 1 and 2 are mathematically described by the following equations:

Memberships of Queue Length (in meters): The membership is given in the three fuzzy sets of short, medium, and long queue length by the equations:

$\mu_{short}(QL) = 1$ $\quad QL < 8$
$= (-1/4) \times (QL - 12)$ $\quad 8 <= QL <= 12$
$= 0$ $\quad 12 < QL$

$\mu_{medium}(QL) = 0$ $\quad QL < 8$
$= (1/4) \times (QL - 8)$ $\quad 8 <= QL <= 12$
$= 1$ $\quad 12 < QL < 16$
$= (-1/4) \times (QL - 20)$ $\quad 16 < QL < 20$
$= 0$ $\quad 20 < QL$

$\mu_{long}(QL) = 0$ $\quad QL < 16$
$= (1/4) \times (QL - 16)$ $\quad 16 <= QL < 20$
$= 1$ $\quad 20 < QL$

Memberships of Traffic Density (in terms of number of cars in the concerned lane): The membership is given in the two fuzzy sets of light and heavy traffic by the equations:

$\mu_{light}(TD) = 1$ $\quad TD < 10$
$= (-1/6) \times (TD - 12)$ $\quad 6 <= TD <= 12$
$= 0$ $\quad 12 < TD$

$\mu_{heavy}(TD) = 0$ $\quad TD < 10$
$= (1/6) \times (TD - 6)$ $\quad 6 <= TD <= 12$
$= 1$ $\quad 12 < TD$

C. *Acquiring Feedback variables:*

Cameras with Bird Eye view may be placed for all the incoming traffic directions, i.e. on the left hand side of each of the four roads leading towards the crossing. The acquired image may be split into three widthwise strips of widths corresponding to the widths of the three lanes allotted for traffic bound towards the right bound direction, the straight moving direction and the left bound one. Image segmentation techniques [4] can be applied for finding the actual Queue length and density are to be applied *only* to the images of the lanes in the direction pair in which the traffic is presently being allowed to move, and not in all the twelve lanes simultaneously.

D. *Matching Degrees for individual Rules and Inference:*

To find the membership value of the antecedents, the actual values of Queue length and traffic density achieved by image processing described above are fitted to the antecedent membership curves described in section B above. The matching degrees for the six fuzzy rules (R2 to R7) are found by finding the minima of the membership values thus found.

The values for T_{adj} are inferred form all the six rules separately.

E. *Defuzzification:*

The inference based on the above rules will give more than one results as more than one rule will be satisfied for most situations. Hence, the result should be combined and defuzzified before further processing. The defuzzification technique being used here is the weighted average of the individual inferences.

The aggregated value of adjustment timing is found as:

$$\mu_{rule\ i} = \min [\{\mu_{antecedent\ 1\ for\ rule\ i}(Q\ L)\}, \{\mu_{antecedent\ 2\ for\ rule\ i}(T\ D)\}]$$

Where,
QL is actual queue length in that lane at that time
And
TD is actual traffic density in that lane at that time.

$$T_{adj\ aggregate} = [\Sigma_i \ \{[\mu_{rule\ i} \times T_{adj\ i}\}] / [\Sigma_i \ \{[\mu_{rule\ i}\ \}]$$

- The time left is found as:
  $T_{left} = T_{left} - T_{min} - T_{adj}$

- Rules 8 onwards are crisp rules
  R8: Restart the timer.
  R9: If ($T_{left} <= 0.2 * T_{max}$)
  Then (Change lights after T_{left})
  Else (Go to rule 1)
- Repeat this for all direction pairs as per the heuristic in 3.1

IV. CONCLUSION:

The System proposed here is very flexible. The timing adjustment ratios and the minimum and maximum time limits can be altered, while keeping the structure of the rule set unchanged. The feedback for the queue lengths and traffic densities can be taken from images taken from cameras above (a bird's eye view). Image processing techniques can be applied to separate the areas of interest (the concerned lanes), and analyze them to find the attributes viz. the density and the length of the queue. Presently, this is a proposed theoretical paper and has only been simulated in a lab, with satisfactory results. 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 at unmanned crossings in the high-speed world today.

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REFERENCES

[1] John Yen, Reza Langari, *Fuzzy Logic: Intelligence, Control, and Information*, Pearson Education; 2005, pp 151-155.

[2] Dan W Patterson, *Artificial Intelligence And Expert Systems*, Prentice Hall of India, 2001, pp 65.

[3] George J. Klir and Tina A. Folger, *Fuzzy Sets, Uncertainty and Information*, Prentice Hall of India, 2004, pp 255-260.

[4] Rafael C. Gonzalez and Richard E Woods, *Digital Image Processing* Prentice Hall of India, 2006, pp27, 567-585.