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# Fuzzy Logic and Its Applications in the Road Traffic System

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**ABSTRACT**

These days, the road traffic system plays an important role in our daily life. The number of vehicles is increasing due to population growth. Consequently, the traffic delay and congestion are growing fast and being a major problem in the world. Due to this traffic problem, our daily life is affected and we have to face many problems such as pollution, accidents, delay in services, wastage of time & money, etc. The improvement of traffic system performance by the traditional control system is difficult. Since fuzzy logic is the best approach to make an automated traffic signal controller, therefore in this paper, we introduce fuzzy logic and its applications for road traffic system.

**Keywords:** Linguistic Variables (LV), Membership Functions (MF), Traffic Light Controller (TLC), Fuzzification, Defuzzification.

## I. INTRODUCTION

In our daily life, the movement of human beings is necessary and due to this, the traffic increases on the road which leads to the traffic congestion or traffic jam [1], therefore fuzzy set theory [2] is applicable to remove traffic congestion because of dealing with uncertainty and ambiguity. The words or sentences like fast, very fast, small, low, very low etc. in natural or artificial languages are taken as linguistic variables [3]. Dharmendra Kumar, J. P. Tripathi et al [4] introduced the role of fuzzification and defuzzification in traffic light controller. In 2008, L. A. Zadeh [5] talked about the need for fuzzy logic and in 2011, M. H. Malhi et al [6] introduced a traffic management system based on vision. Shoaib Kamran et al [10] proposed a controller based on real time GPS data which identifies the traffic patterns and works according to the vehicle behaviours. Thus; too many traffic light controllers were developed by taking different – different inputs to get the appropriate outputs [7], [8], [9]. Some traffic light controllers [11], [12] were developed for emergency vehicles.

## II. FUZZY LOGIC

A many valued logic having truth values in between completely false and completely true is called fuzzy logic. If completely false is denoted as '0' and completely true is denoted as '1', then truth value is any real number in the interval [0, 1].

If the truth value is either 0 or 1, then the logic is said to be Boolean logic.

## III. FUZZY SET AND MEMBERSHIP FUNCTION

Let X be a universe of discourse and let x be an element of X. Then, the fuzzy set $\tilde{A}$ is a collection of ordered pairs $\left(x, \mu_{\tilde{A}}(x)\right)$, i.e.,

$$\tilde{A} = \left\{\left(x, \mu_{\tilde{A}}(x)\right) : x \epsilon X\right\}$$

where $\mu_{\tilde{A}}(x)$ is a function from X to the interval [0, 1] and this function is known as membership function. It gives the degree of truth to which $x \epsilon \tilde{A}$. It is the generalization of the characteristic function of crisp set.

The membership function of a fuzzy set $\tilde{A}$ (tilde underscore) is given as

$$\mu_{\tilde{A}} : X \to [0,1] \text{ such that}$$

$$\mu_{\tilde{A}}(x) = degree\ to\ which\ x \epsilon \tilde{A}.$$

**NOTE:** Larger membership grades denote higher degrees of set membership.

## IV. REPRESENTATION OF FUZZY SET

In 1965, Zadeh introduces two operators Σ and ∫ to represent a fuzzy set. The symbol Σ is used for the collection or aggregation of elements while the symbol ∫ is used for continuous function – theoretic aggregation.

**(i)** When X (universe of discourse) is finite and discrete, then the symbol Σ is used to represent the fuzzy set, i.e.,

$$\tilde{A} = \left\{\frac{\mu_{\tilde{A}}(x_1)}{x_1} + \frac{\mu_{\tilde{A}}(x_2)}{x_2} + \cdots\cdots\right\} = \left\{\sum_i \frac{\mu_{\tilde{A}}(x_i)}{x_i}\right\}$$

here the horizonal bar (-) is a delimiter, not a quotient.

**(ii)** When X (universe of discourse) is continuous and infinite, then the symbol ∫ is used to represent the fuzzy set, i.e.,

$$\tilde{A} = \left\{\int \frac{\mu_{\tilde{A}} x}{x}\right\}$$

## V. FUZZY NUMBER

A fuzzy set $\tilde{A}$ on real line is said to be a fuzzy number if it satisfies the following properties –

(i) $h(\tilde{A}) = 1$, i.e., $\tilde{A}$ is normal.

(ii) $\alpha - cut\ of\ \tilde{A}$ is a closed interval for every $\alpha \in [0, 1]$, and

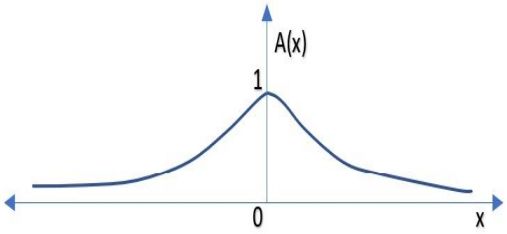
(iii) Support of $\tilde{A}$ is bounded.

## VI. TYPES OF FUZZY NUMBER

### A. QUASI FUZZY NUMBER

A fuzzy number $\tilde{A}$ on R is said to be a quasi-fuzzy number if it satisfies the limit conditions

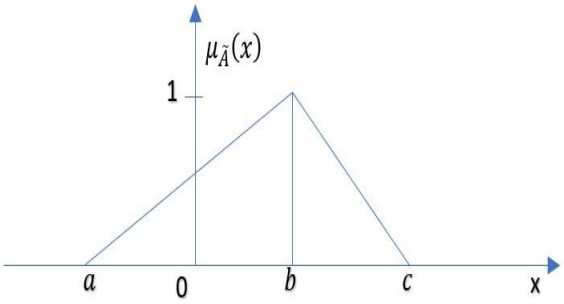
$$\lim_{x \to \infty} \mu_{\tilde{A}}(x) = 0, \lim_{x \to -\infty} \mu_{\tilde{A}}(x) = 0$$




### B. TRIANGULAR FUZZY NUMBER

A fuzzy number $\tilde{A}$ constituted with three points $(a, b, c)$ is said to be a triangular fuzzy number if its membership function is defined as;

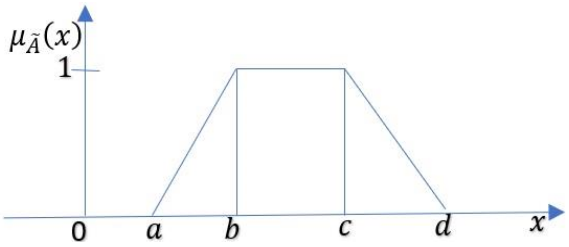
$$\mu_{\tilde{A}}(x) = \begin{cases} 0 & , \quad x < a \\ \dfrac{x-a}{b-a} & , \quad a \le x \le b \\ \dfrac{c-x}{c-b} & , \quad b \le x \le c \\ 0 & , \quad x > c \end{cases}$$




## C. TRAPEZOIDAL FUZZY NUMBER

A fuzzy number $\tilde{A}$ constituted with four points $(a, b, c, d)$ is said to be a trapezoidal fuzzy number if its membership function is defined as;

$$\mu_{\tilde{A}}(x) = \begin{cases} 0 & , \quad x < a \\ \dfrac{x-a}{b-a} & , \quad a \le x \le b \\ 1 & , \quad b \le x \le c \\ \dfrac{d-x}{d-c} & , \quad c \le x \le d \\ 0 & , \quad x > d \end{cases}$$




## VII. LINGUISTIC VARIABLES

The variables whose states are fuzzy numbers representing linguistic concepts, such as very large, large, medium, small, and so on, as taken in a particular context, are called linguistic variables.

## VIII. FUZZIFICATION

The process of converting a crisp quantity into a fuzzy quantity is known as fuzzification. Sometimes, fuzzification is used to convert a fuzzy set into a fuzzier set. By this operation, a crisp input value is translated into a linguistic variable.

Let $A = \left\{\frac{\mu_i}{x_i} : x_i \in X\right\}$ be a fuzzy set. Then we have to find fuzzified set $\tilde{A}$. For this, we use a common fuzzification algorithm.

At first, we keep $\mu_i$ as constant and then transform $x_i$ into a fuzzy set $Q(x_i)$ representing the expression about $x_i$. This fuzzy set $Q(x_i)$ is taken as the kernel of fuzzification.

Now; the fuzzified set $\tilde{A}$ is given as

$$\tilde{A} = \mu_1 Q(x_1) + \mu_2 Q(x_2) + \mu_3 Q(x_3) + \cdots + \mu_n Q(x_n)$$

where the symbol ~ means fuzzified.

## IX. DEFUZZIFICATION

The process of converting a fuzzy quantity into a crisp quantity is known as fuzzification. Defuzzification is a decision – making algorithm which gives the best crisp results based on the fuzzy set. Thus; defuzzification is the reverse process of fuzzification.

## X. CONCLUSION

In traffic light controller, we choose inputs and assign their membership functions using fuzzification. These fuzzy inputs are converted into fuzzy outputs by FIS using fuzzy rule. Defuzzification is applied to fuzzy outputs to get crisp outputs. The triangular membership functions are used due to computational efficiency.

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