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The Best Way to Access Gas Stations using Fuzzy Logic Controller in a Neutrosophic Environment

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Abstract

These days, Google Map is used to find any location and/or to define the route to any given place. Its accuracy is up to 30 meters but if neutrosophic numbers are used, it gives more accuracy. To check the implementation of neutrosophic numbers in Google Map, a system is developed based on Fuzzy Logic Controller (FLC) using neutrosophic numbers to find the gas station which is nearest, less parking car units and with few traffic signals on the way. In this way, it takes less time to reach the available gas station. This system enables the driver to find a fuel station with more accuracy. We took five linguistic inputs including distance, gas availability, parking car unit, amount of gas, and the number of traffic signals to get one output, that is, time. We assigned different neutrosophic soft sets to each linguistic input. FLC inference was designed using 108 rules based on if-then statements to select time to reach the gas station. The results were verified by MATLAB's Fuzzy Logic Toolbox.

Keywords: FLC, neutrosophic numbers, fuzzy toolbox, linguistic inputs, accuracy function

Introduction

In 1965, the concept of fuzzy set was proposed by Zadeh [1]. Fuzzy Logic (FL) is linked with the fuzzy set theory which is an extension of the crisp set theory. Crisp sets or classical sets follow a bi-valued logic (Boolean logic). Crisp logic deals with exact or precise information. The crisp set C of universe Y is defined by a function called membership function or characteristic function $\mu_C(y)$ such that

$$\mu_C(y): Y \rightarrow \{0,1\}$$

where

$$\mu_C(y) = \begin{cases} 1 \ \ if \ y \ \in C \\ 0 \ if \ y \ \notin C \end{cases}$$

Fuzzy logic deals with vague, uncertain and/or imprecise information rather than exact information. The basic concept of fuzzy logic comprises linguistic variables and the values of these variables are words instead of numbers [2, 3, 4]. These are represented by fuzzy sets and are characterized by a membership function. Fuzzy logic is a form of multi-valued logic and it may have truth values between 0 and 1 (including 0 and 1) [5, 6, 7]. A fuzzy set $\tilde{F}$ of Y is defined by a function known as the characteristic function or membership function $\mu_{\tilde{F}}(y)$ of fuzzy set $\tilde{F}$ such that

$$\mu_{\tilde{F}}(y): Y \rightarrow [0,1]$$

where

$$\mu_{\tilde{F}}(y) = 1 \text{ if } y \text{ is totally in } F$$
$$\mu_{\tilde{F}}(y) = 0 \text{ if } y \text{ is not in } F$$
$$0 < \mu_{\tilde{F}}(y) < 1 \text{ if } y \text{ is partly in } F$$

The applications of fuzzy sets in various fields are discussed by George J. Klir and Bo Yuan [8] and Timothy [9]. In 1974, Mamdani conducted the first fuzzy logic based control experiment for a steam engine [10]. Fuzzy logic systems are used in traffic, medical science, securities, transportation, and electronic devices such as cameras, rice cookers, dishwashers, air conditioners, washing machines, microwave ovens and many other home appliances, as well as in the industrial sector. Many home appliances have been improved using fuzzy logic to conserve electricity and to save time. Fuzzy set theory and its application in decision making have been studied by many researchers [11, 12, 13, 14, 15, 16, 17, 18, 19, 20].

Fuzzy controller is a control system based on fuzzy logic. A Fuzzy Logic Controller (FLC) is a mathematical system that takes on continuous values between 0 and 1 and it examines analog input values in terms of logical variables [21, 22]. It mainly consists of three parts: fuzzifier, fuzzy inference engine and defuzzifier.

Sometimes, it becomes very difficult to assign membership value to fuzzy sets. Consequently, researchers have devised many other tools to avoid difficulties in handling ambiguous and uncertain data. Some of these tools include intuitionist fuzzy numbers [23] and rough sets [24]. Intuitionist fuzzy sets only deal with incomplete information by considering both membership function (truth membership) and non-membership function (falsity membership) [25]. While dealing with some real life problems in information system, belief system and expert system, we need to work with indeterminate and incomplete information. Neutrosophic set is defined by Smararndache [26]. It is a mathematical tool for handling problems involving indeterminate, imprecise and inconsistent data. In the universe of discourse X, a neutrosophic set A is defined as

$$A = \{< x, T_A(x), I_A(x), F_A(x) >: x \in X\}$$

where the functions $T, I, F : X \rightarrow [0,1]$

and

$$0 \leq T_A(x) + I_A(x) + F_A(x) \leq 3$$

where $T_A(x)$, $F_A(x), I_A(x)$ defines the degree of membership, degree of non-membership and the degree of indeterminacy respectively of each element to the set A.

Maji [27] combined soft set with neutrosophic set and introduced the theory of neutrosophic soft set. The author described the equality of two super sets and super soft sets, super set and subset of a neutrosophic soft set, complement of a neutrosophic soft set, null neutrosophic soft set and absolute neutrosophic soft set. Binary operations such as OR, AND, union, intersection and De Morgan's Law with examples were applied on neutrosophic soft set.

The researcher identified the location of fuel station and designed a smart system that automatically indicates the quantity of fuel in the tank. It also indicates the nearest fuel station when there is a low amount of fuel left in the tank through digital displays embedded in vehicles and maps. Jafar et al. [28, 29, 30] worked on decision-making problems within a neutrosophic environment. Saqlain et al. [31, 32, 33] worked on neutrosophic and neutrosophic hypersoft environment.

In this research, a new method is developed based on FLC using neutrosophic numbers to identify the location of a particular fuel station in unfamiliar areas which takes less time to reach.

2. Statement of Problem

These days, Google Map is used to find the location and/or to define the route to any given place. It has an accuracy of up to 30 meters. This accuracy can be improved by designating neutrosophic numbers as membership values.

2.1. Case Study

Driver / user may forget to check the fuel tank before the start of a long journey or while travelling to distant places. The driver may not know the location of petrol pump in an unknown locality. Other issues regarding vehicles (breakdown, puncture) may also cause the driver to panic while travelling.

2.2. Objective

To check the implementation of this number in Google Map, a system is developed based on FLC using neutrosophic numbers. The objective of this research is to bring more accuracy in locating a fuel station that takes less time to reach.

2.3. Proposed Model

A model based on FLC is designed in this research which relies on five linguistic inputs and one linguistic output to locate a fuel station.

Linguistic inputs include the following:

1. Distance
2. Gas availability
3. Parking Car Unit (PCU)
4. Amount of gas
5. Number of traffic signals

Table 1. Linguistic Inputs

Linguistic Inputs					
No.	**Distance**	**Gas Availability**	**Parking Car Unit**	**Amount of Gas**	**Number of Traffic Signals**
1	Small	Yes	Less	Yes	1
2	Medium	No	Medium	No	2
3	Large		High		3

Linguistic output comprises time.

Figure 1 shows the basic approach to FLC. This system is based on FLC and it consists of three parts, that is, fuzzifier, inference engine (fuzzy rule selector) and defuzzifier. FLC inference engine was designed using 108 rules based on if-then statements to select time to reach the gas station. We assigned different neutrosophic soft sets to each linguistic input.

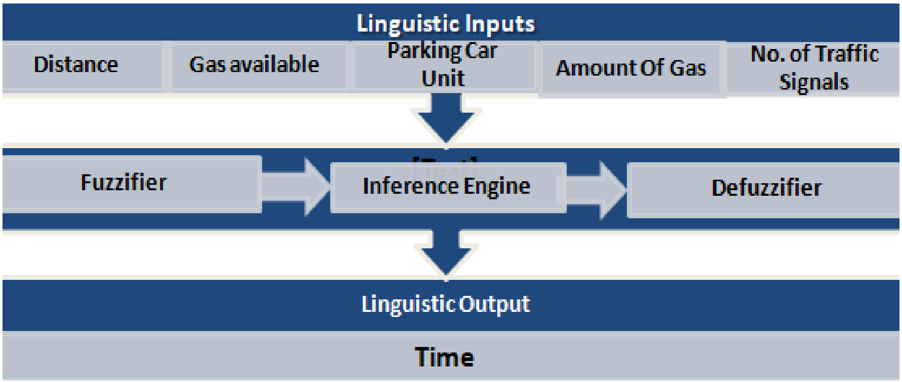

Figure 1. Basic approach to FLC

Table 2. Neutrosophic Inputs

	Representation	Symbol	Neutrosophic Soft Sets
	Distance		
1	Small	S	(0.2,0.4,0.6)
2	Medium	M	(0.3,0.1,0.9)
3	Large	L	(0.7,0.9,0.3)
	Gas Availability		
1	Yes	Y	(0.9,0.6,0.2)
2	No	N	(0.1,0.8,0.9)
	Parking Car Unit (PCU)		
1	Less	L	(0.4,0.6,0.5)
2	Medium	M	(0.6,0.7,0.8)
3	High	H	(0.8,0.1,0.4)
	Amount of Gas		
1	Yes	Y	(0.7,0.2,0.9)
2	No	N	(0.8,0.1,0.4)
	Number of Traffic Signals		
1	1		(0.7,0.8,0.5)
2	2		(0.5,0.7,0.6)
3	3		(0.4,0.6,0.7)

108 rules were formed using linguistic inputs to obtain the said linguistic output, that is, time. It was analyzed in terms of conditional statements (if-then statement) given below,

Rule 1

If (distance is S) and (gas availability is Y) and (PCU is L) and (amount of gas is Y) and (number of traffic signals is 1) then (time is X).

Rule 2

If (distance is S) and (gas availability is Y) and (PCU is L) and (amount of gas is Y) and (number of traffic signals is 2) then (time is X).

Rule 3

If (distance is S) and (gas availability is Y) and (PCU is L) and (amount of gas is Y) and (number of traffic signals is 3) then (time is X).

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Rule 108

If (distance is H) and (gas availability is Y) and (PCU is H) and (amount of gas is Y) and (number of traffic signals is 3) then (time is XXXXXXXXX).

By assigning neutrosophic soft sets to each linguistic variable, we solved the above 108 rules using the following formula of the intersection of two neutrosophic soft sets:

$$\mathrm{T}_{\mathrm{K(e)}}(\mathrm{m}) = \min\left(\mathrm{T}_{\mathrm{H(e)}}(\mathrm{m}), \mathrm{T}_{\mathrm{G(e)}}(\mathrm{m})\right)$$

$$\mathrm{I}_{\mathrm{K(e)}}(\mathrm{m}) = \frac{\mathrm{I}_{\mathrm{H(e)}}(\mathrm{m}) + \mathrm{I}_{\mathrm{G(e)}}(\mathrm{m})}{2}$$

$$\mathrm{F}_{\mathrm{K(e)}}(\mathrm{m}) = \max\left(\mathrm{F}_{\mathrm{H(e)}}(\mathrm{m}), \mathrm{F}_{\mathrm{G(e)}}(\mathrm{m})\right), \forall \mathrm{e} \in \mathrm{C}$$

Rule 1

$$\overbrace{[(0.2,0.4,0.6) \cap (0.9,0.6,0.2)]}^{\boldsymbol{A}} \cap \overbrace{[(0.4,0.6,0.5) \cap (0.7,0.2,0.9)]}^{\boldsymbol{B}} \cap (0.7,0.8,0.5) \qquad (1)$$

$$F_h e(x) \cap F_g e(x) = [(0.2,0.4,0.6) \cap (0.9,0.6,0.2)]$$

$$\min\,(0.2,0.9) = 0.2$$

$$\frac{0.4 + 0.6}{2} = \frac{0.10}{2} = 0.5$$

$$\max\,(0.6,0.2) = 0.6$$

$F_l e(x) = [(0.2,0.4,0.6) \cap (0.9,0.6,0.2)] = (0.2,0.5,0.6)$
(A)
$F_i e(x) \cap F_j e(x) = [(0.4,0.6,0.5) \cap (0.7,0.2,0.9)]$
$\min(0.4,0.7) = 0.4$
$$\frac{0.6 + 0.2}{2} = \frac{0.8}{2} = 0.4$$
$\max(0.5,0.9) = 0.9$
$F_m e(x) = [(0.4,0.6,0.5) \cap (0.7,0.2,0.9)] = (0.4,0.4,0.9)$
(B)
Put (A) and (B) in (1)
$(0.2,0.5,0.6) \cap (0.4,0.4,0.9) \cap (0.7,0.8,0.5)$
(2)
$F_l e(x) \cap F_m e(x) = [(0.2,0.5,0.6) \cap (0.4,0.4,0.9)]$
$\min(0.2,0.4) = 0.2$
$$\frac{0.5 + 0.4}{2} = \frac{0.9}{2} = 0.45$$
$\max(0.6,0.9) = 0.9$
$F_n e(x) = [(0.2,0.5,0.6) \cap (0.4,0.4,0.9)] = (0.2,0.45,0.9)$
(2) becomes
$F_n e(x) \cap F_k e(x) = [(0.2,0.45,0.9) \cap (0.7,0.8,0.5)]$
$\min(0.2,0.7) = 0.2$
$$\frac{0.45 + 0.8}{2} = \frac{1.25}{2} = 0.625$$
$\max(0.9,0.5) = 0.9$
$F_o e(x) = [(0.2,0.45,0.9) \cap (0.7,0.8,0.5)] = (0.2,0.625,0.9)$
$F_o e(x) = (0.2,0.4,0.6) \cap (0.9,0.6,0.2) \cap (0.4,0.6,0.5) \cap (0.7,0.2,0.9) \cap (0.7,0.8,0.5)$
$= (0.2,0.625,0.9)$

Then, we converted this neutrosophic number to crisp number using the accuracy function given below:

$$\text{Accuracy Function} = A_F(N) = \frac{T(x) + I(x) + F(x)}{3} = \frac{0.2 + 0.625 + 0.9}{3} = 0.58$$

Similarly, we solved all other rules

Table 3. Application of Accuracy Function

Sr.#	**Distance**	**Gas Available**	**Parking Car Unit (PCU)**	**Amount of Gas**	**Number of Traffic Signals**	**Output**	**Accuracy Function** $= A_F(N) = \frac{T(x)+I(x)+F(x)}{3}$
1	(0.2,0.4,0.6)	(0.9,0.6,0.2)	(0.4,0.6,0.5)	(0.7,0.2,0.9)	(0.7,0.8,0.5)	(0.2,0.63,0.9)	0.58
2	(0.2,0.4,0.6)	(0.9,0.6,0.2)	(0.4,0.6,0.5)	(0.7,0.2,0.9)	(0.5,0.7,0.6)	(0.2,0.58,0.9)	0.56
3	(0.2,0.4,0.6)	(0.9,0.6,0.2)	(0.4,0.6,0.5)	(0.7,0.2,0.9)	(0.4,0.6,0.7)	(0.2,0.53,0.9)	0.54
4	(0.2,0.4,0.6)	(0.9,0.6,0.2)	(0.4,0.6,0.5)	(0.8,0.1,0.4)	(0.7,0.8,0.5)	(0.2,0.61,0.9)	0.47
5	(0.2,0.4,0.6)	(0.9,0.6,0.2)	(0.4,0.6,0.5)	(0.8,0.1,0.4)	(0.5,0.7,0.6)	(0.2,0.56,0.6)	0.45
6	(0.2,0.4,0.6)	(0.9,0.6,0.2)	(0.4,0.6,0.5)	(0.8,0.1,0.4)	(0.4,0.6,0.7)	(0.2,0.51,0.7)	0.47
7	(0.2,0.4,0.6)	(0.9,0.6,0.2)	(0.6,0.8,0.7)	(0.7,0.2,0.9)	(0.7,0.8,0.5)	(0.2,0.65,0.7)	0.58
8	(0.2,0.4,0.6)	(0.9,0.6,0.2)	(0.6,0.8,0.7)	(0.7,0.2,0.9)	(0.5,0.7,0.6)	(0.2,0.6,0.9)	0.57
9	(0.2,0.4,0.6)	(0.9,0.6,0.2)	(0.6,0.8,0.7)	(0.7,0.2,0.9)	(0.4,0.6,0.7)	(0.2,0.55,0.9)	0.55
10	(0.2,0.4,0.6)	(0.9,0.6,0.2)	(0.6,0.8,0.7)	(0.8,0.1,0.4)	(0.7,0.8,0.5)	(0.2,0.64,0.7)	0.51
11	(0.2,0.4,0.6)	(0.9,0.6,0.2)	(0.6,0.8,0.7)	(0.8,0.1,0.4)	(0.5,0.7,0.6)	(0.2,0.59,0.7)	0.5
12	(0.2,0.4,0.6)	(0.9,0.6,0.2)	(0.6,0.8,0.7)	(0.8,0.1,0.4)	(0.4,0.6,0.7)	(0.2,0.54,0.7)	0.48
13	(0.2,0.4,0.6)	(0.9,0.6,0.2)	(0.8,0.1,0.4)	(0.7,0.2,0.9)	(0.7,0.8,0.5)	(0.2,0.56.0.9)	0.55
14	(0.2,0.4,0.6)	(0.9,0.6,0.2)	(0.8,0.1,0.4)	(0.7,0.2,0.9)	(0.5,0.7,0.6)	(0.2,0.51.0.9)	0.54
15	(0.2,0.4,0.6)	(0.9,0.6,0.2)	(0.8,0.1,0.4)	(0.7,0.2,0.9)	(0.4,0.6,0.7)	(0.2,0.46.0.9)	0.52
-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-
108	(0.7,0.9,0.3)	(0.9,0.6,0.2)	(0.8,0.1,0.4)	(0.7,0.2,0.9)	(0.4,0.6,0.7)	(0.4,0.53,0.9)	0.61

2.4. Significance

The use of neutrosophic numbers instead of fuzzy numbers in Google Map gives more accuracy in locating the desired place. A system based on FLC which uses neutrosophic numbers enables us to get more accuracy in locating a fuel station that takes less time to reach.

3. Achievements

3.1. Comparison of MATLAB Results with Calculated Results

We calculated results from MATLAB Fuzzy Toolbox and compared them with calculated results.

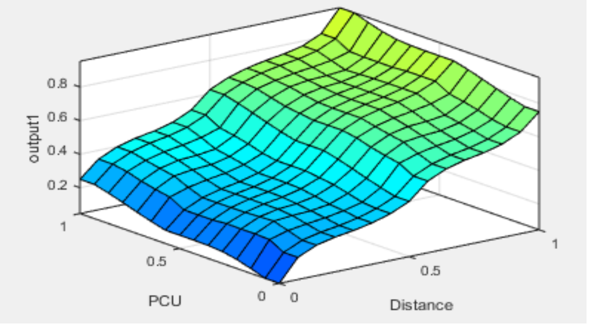

Figure 2. Relation between distance and PCU MATLAB fuzzy toolbox view

The above graph shows the relationship of distance and PCU with time. As we move away from the origin, distance and PCU increase and time also increases.

A direct relationship between PCU and distance verification of the above graph can be seen below based on calculated results.

Table 4. Relation between Distance and PCU MATLAB Fuzzy Toolbox Linguistic View

Distance	Gas Availability	Parking Car Unit (PCU)	Amount of Gas	Number of Traffic Signals	Output
S	Y	L	Y	1	0.58
M	Y	M	Y	1	0.6

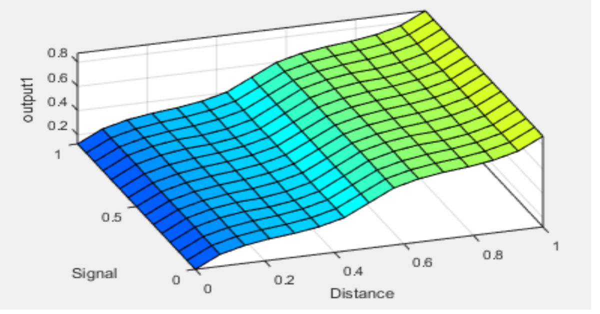

Figure 3. Relation between distance and signal MATLAB fuzzy toolbox view

The above graph shows the relationship between distance and signal with time. As we move away from the origin, distance and signal increase and time also increases.

A direct relationship between PCU and distance verification of the above graph can be seen below based on calculated results.

Table 5. Relation between Distance and Signal MATLAB Fuzzy Toolbox View

Distance	Gas Availability	Parking Car Unit (PCU)	Amount of Gas	Number of Traffic Signals	Output
S	Y	H	Y	1	0.55
L	Y	H	Y	3	0.61

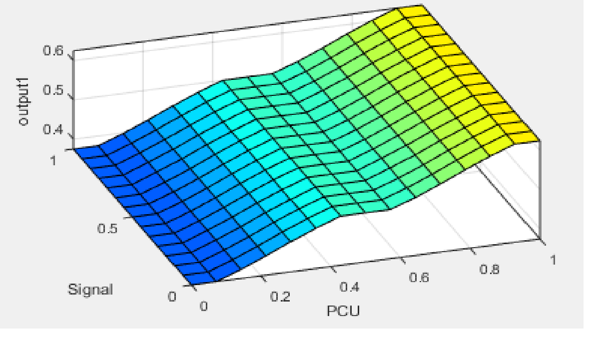

Figure 4. Relation between PCU and signal MATLAB fuzzy toolbox view

The above graph shows the relationship between PCU and signal with time. As we move away from the origin, PCU and signal increase and time also increases.

A direct relationship between PCU and distance verification of the above graph can be seen below based on calculated results.

Table 6. Relation between PCU and Signal MATLAB Fuzzy Toolbox View

Distance	Gas Availability	Parking Car Unit (PCU)	Amount of Gas	Number of Traffic Signals	Output
M	Y	L	Y	1	0.58
M	Y	M	Y	2	0.59

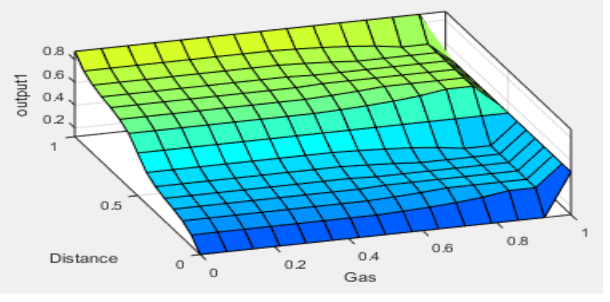

Figure 5. Relation between gas and distance MATLAB fuzzy toolbox view

The above graph shows the relationship of the amount of gas and signal with time. As we move away from the origin, distance and signal increase and time also increases.

A direct relationship with PCU and distance verification of the above graph can be seen below based on calculated results.

Table 7. Relation between Gas and Distance MATLAB Fuzzy Toolbox View

Distance	Gas Availability	Parking Car Unit (PCU)	Amount of Gas	Number of Traffic Signals	Output
M	Y	L	Y	1	0.58
L	Y	L	Y	1	0.66

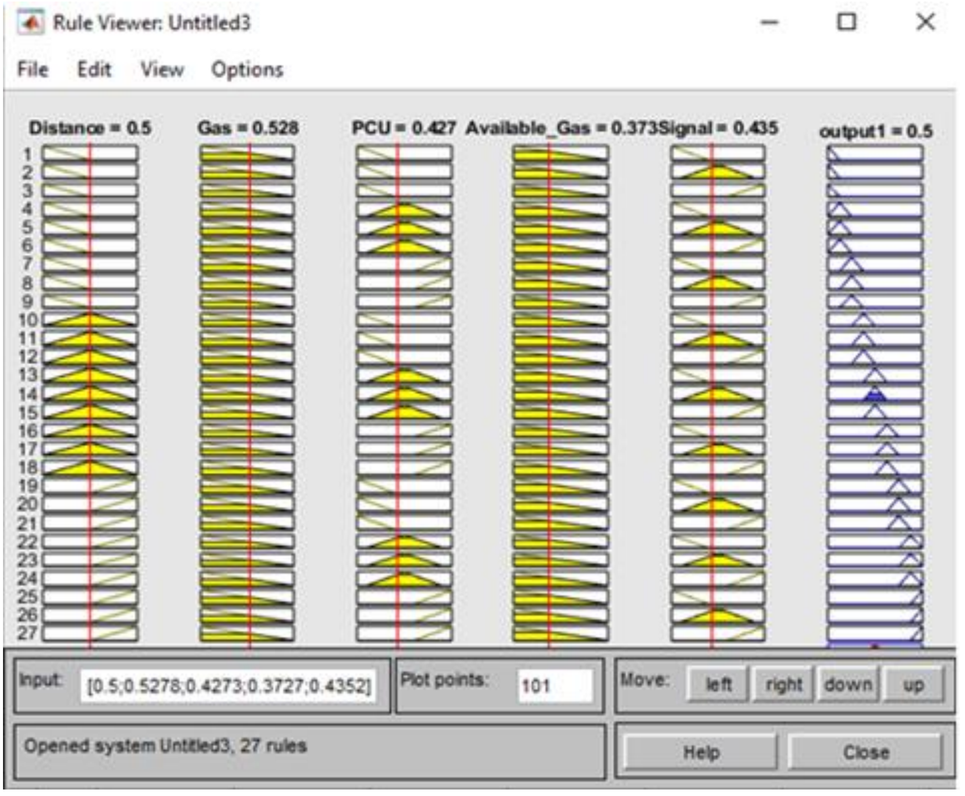

Figure 6. MATLAB's rule viewer

When we select Distance M = 0.5, Amount of Gas Y =0.528, PCU M = 0.427, Gas Availability Y = 0.373, Number of Traffic Signals 2 = 0.435, then Output is 0.5.

Also from the calculation,

Table 8. MATLAB Results and Neutrosophic Soft Set Results

Distance	**Gas Availability**	**Parking Car Unit (PCU)**	**Amount of Gas**	**Number of Traffic Signals**	**Output**
S	Y	M	N	2	0.5

MATLAB results and neutrosophic soft set results are approximately the same.

4. Conclusion

We used Neutrosophic numbers to calculate the output, that is, time. Neutrosophic numbers were used as membership values in FLC and the results were calculated in MATLAB's Fuzzy Logic Toolbox. Also, these results were verified by taking neutrosophic soft numbers as membership functions and manually calculated by applying aggregate operators of neutrosophic numbers. So, in the future, neutrosophic numbers can be used as membership values in FLC to obtain accuracy.

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