Application of Mamdani Method on Fuzzy Logic to Decision Support of Traffic Lights Control System at a Crossing of Malang City

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Abstract: Adaptive traffic management system has been implemented using fuzzy logic control. This study supposed to design a traffic light system with fuzzy logic using defuzzification Mamdani method on fuzzy logic. Establishment of fuzzy sets by defining variables are vehicle volume, road capacity, and green light duration for three fuzzy sets i.e. small, medium, and large. Fuzzy rules are formed to express relation between input and output which is an implication. Composition between the implication functions using the MAX function combine the fuzzy sets of each rule and defuzzification with the centroid method. Case study is conducted at the ITN crossing that was resulted in the timing of a change of traffic light from Department of Transportation of Malang City cause still was not effective to break down the congestion. This can be seen from the duration (in seconds) on a leg of the crossing with an incomparable vehicle volume. Plot data of vehicle volume with green light duration of Transportation Department of Malang that vehicle volume is larger has shorter duration of green light, and otherwise. Furthermore, the Mamdani method on fuzzy logic gives solution as control system for the setting of traffic light more effective.

1 INTRODUCTION

Increasing the number of vehicles, especially in the city of Malang, especially in the city of students to make jams become one of the important problems that must be resolved. This situation is usually observed from a crossroads with many queues of vehicles going through a crossroads. Traffic flow at the crossroads in the city of Malang has many that are set using traffic lights. The use of traffic lights at intersections is intended to control traffic flow in order to avoid prolonged congestion. In the development of complex traffic light control systems have been applied adaptive traffic management system by using the control of fuzzy logic or logic (P. Mahalakshmi and K. Ganesan, 2015). The basic concept of an adaptive strategy used to manage membership functions according to traffic conditions in order to work optimally (Jang, 1997). Adaptive setting system will take into account the uncertain traffic conditions to optimize the flow of traffic in accordance with the circumstances.

The state of traffic under consideration is limited to the circumstances in an intersection area only. In fact, traffic conditions on the highway between intersections with each other are related. Traffic at an intersection, the number of passing vehicles, can be used to predict traffic conditions at the next intersection. In this research will describe the design of traffic light control system with fuzzy logic control. This system will consider the prediction of traffic conditions as inputs or inputs in determining the duration of the green light on a traffic light. So, it is expected that this concept can provide the duration of green time corresponding to the number of queues of vehicles that will cross the intersection. In the previous research there is Mamdani Fuzzy inference system Application Setting for Traffic Lights (Sumiati et al, 2014) which will develop in Malang City.

2 RESULTS AND DISCUSSION

2.1 The Establishment of the Fuzzy Set

The traffic control system in Malang City consists of three input variables namely vehicle, volume and road capacity and one output variable are duration of

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green lamp. Determination of input variables used in this study based on data from the Department of Transportation of Malang City is the input variable vehicle volume (smp/hour) and input variables road capacity (smp/hour) as a benchmark to determine the universe of speech. While the output variable Green Length Duration obtained from the maximum duration of the green light at the intersection of 120 seconds and then divided as many as the intersection of legs attached red light posts as much as three feet intersection at intersection ITN Malang. So, the output variable Duration of Green Lights during maximum 40 seconds on each legs of intersection. Based on the domain, we determined the membership function of each variable (Lin & Lee, 1996). Based on the data that exists by using the theory of quartile on statistics (Md. Amjad Hossain et al, 2011). Table 1 and table 2 contain the design of fuzzy set in traffic control system in Malang City.

Table 1: Fuzzy Set Table (Input).

VARIABLE	THE SET	DOMAIN
Volume of Vehicles (smp/hour)	Smoothly	[702, 825]
	Effective	[763, 887]
	Dense	[825, 948]
Road Capacity (smp/hour)	Less	[850, 969]
	Enough	[909, 1029]
	Surfeited	[696, 1088]

Table 2: Fuzzy Set Table (Output).

VARIABLE	THE SET	DOMAIN
Green Light Duration (seconds)	Fast	[0 20]
	Medium	[10 30]
	Slow	[20 40]

The fuzzy set and the membership function of the Green Length Duration variable based on the Vehicle Volume variables and the Road Capacity variables are represented as figure 1, 2, and 3.

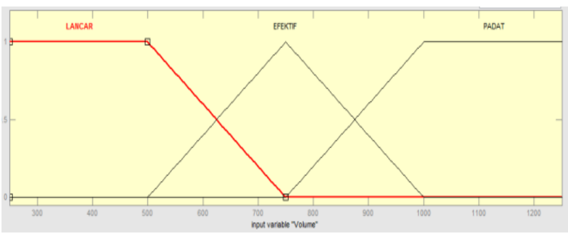

Figure 1: Set of Fuzzy Volume of Vehicle Variable.

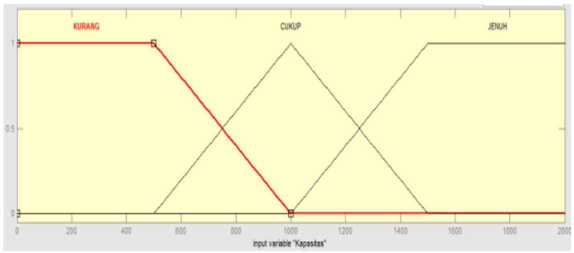

Figure 2: Set of Fuzzy Road Capacity Variable.

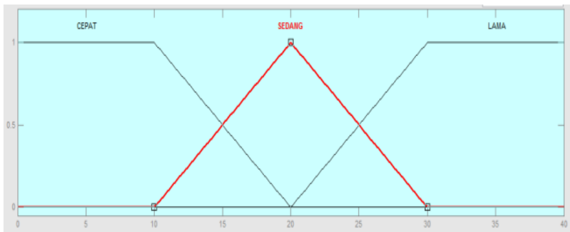

Figure 3: Set of Fuzzy Green Light Duration Variable.

2.2 Application of Implication Function

The rules are formed to express the relation between input and output. Each rule is an implication. The operator used to connect between two inputs is the AND operator, and that maps between input-output is IF-THEN. Propositions that follow the IF are called antecedents, whereas the proposition that follows the THEN is called consequent.

Table 3: Table of Implication Function.

Green Light Duration		**Road Capacity**		
		Less	Enough	Surfeited
Volume of Vehicles	Smoothly	Fast	Fast	Fast
	Effective	Fast	Medium	Medium
	Dense	Medium	Slow	Slow

In the Mamdani Method, the implication function used is MIN, which means the membership function obtained as a consequence of this process is the minimum value of the vehicle volume and road capacity variables. So, we get fuzzy area on green lamp duration variable for each rule.

2.3 Defuzzification

The composition between the implication functions using the MAX function is by retrieving the maximum value from the rule output then combining the fuzzy regions of each rule with the OR operator (Nguyen, 2003).

$$\mu_{sf}[x] = max(\mu_{kf_1}[x], \mu_{kf_2}[x] \cdots, \mu_{kf_9}[x]),$$

where $\mu_{sf}[x]$ is the value of the fuzzy solution membership until the i-rule and $\mu_{kf}[x]$ is the consequent membership value of each fuzzy rule to-i, with $i = 1, 2, \ldots, 9$. The crisp solution is obtained by taking the center point (Z_0) fuzzy area. Generally formulated:

$$Z_0 = \frac{\int_a^b \mu_{(Z)}\, z\, dz}{\int_a^b \mu_{(Z)} dz},$$

for the continuous domain, with is the value of the defuzzification result and the membership function of that point, whereas z is the value of the i-th domain.

2.4 Determination of Green Light Duration

The fuzzy set used in this study to determine the duration of the green light in traffic control system in Malang City based on the policy of Transportation Department of Communication and Information Malang. The fuzzy set includes the variable volume of the vehicle and the capacity of the road as input, and the duration of the green light as output. ITN junction has 4 legs intersection as follows:

- West Leg : Bend. Sigura – gura Street
- East Leg : Veteran Street
- South Leg : Bend. Sutami Street
- North Leg : Sumber Sari Street

Here's the proportion of traffic flow at the busiest hour:

Table 4: Traffic Flow.

Time	Leg	Volume of Vehicles (smp/hour)	Road Capacity (smp/hour)
Busy Time	WEST	702	850
	EAST	914	1088
	SOUTH	948	1102
	NORTH	780	974

The current traffic system in Malang City based on the survey result is traffic flow from the north leg intersection Sumber Sari Street diverted directly to the east leg intersection Veteran Street. So, the north leg intersection Sumber Sari Street are not found in red light posts. To set up a traffic control system based on fuzzy logic, there are three cases of traffic flow analysis from three legs namely Bend. Sigura-gura Street, Veteran Street, and Bend. Sutami Street.

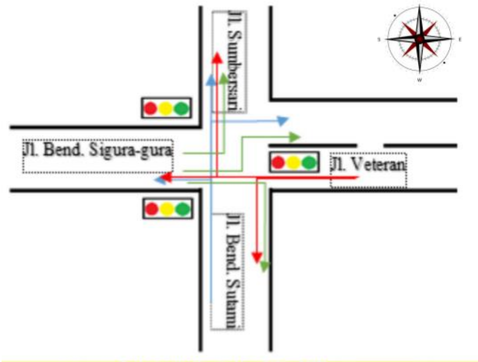

Figure 4: Cross of ITN in Malang.

2.4.1 Determination of Green Light from West Cross Leg

The vehicle volume on the west cross leg is 702 smp/hour which included in the fuzzy set of SMOOTHLY and EFFECTIVE. The membership function for SMOOTHLY is

$$\mu_{smoothly}(x) = \begin{cases} 1, & x < 500, \\ \frac{750 - x}{250}, & 500 \le x < 750, \\ 0, & x \ge 750. \end{cases}$$

Therefore, the vehicle volume on the west cross leg is 702 smp/hour in the fuzzy set of SMOOTHLY, we obtain

$$\mu_{smoothly}(702) = \frac{750 - 702}{250} = 0.192.$$

The membership function for EFFECTIVE is

$$\mu_{effective}(x) = \begin{cases} 0, & x < 500, \\ \frac{x - 500}{250}, & 500 \le x < 750, \\ \frac{1000 - x}{250}, & 750 \le x < 1000, \\ 0, & x \ge 1000. \end{cases}$$

Therefore, the vehicle volume on the west cross leg is 702 smp/hour in the fuzzy set of EFFECTIVE, we obtain

$$\mu_{effective}(702) = \frac{702 - 500}{250} = 0.808.$$

Therefore, the volume of vehicles can be said smoothly with 19.2% membership function. And the volume of vehicles can be said to be effective with the membership function of 80.8%.

The road capacity is 850 smp/hour which included in the fuzzy set of LESS and ENOUGH. The membership function of LESS is

$$\mu_{less}(x) = \begin{cases} 1, & x < 500, \\ \frac{1000 - x}{500}, & 500 \le x < 1000, \\ 0, & x \ge 1000, \end{cases}$$

and

$$\mu_{less}(850) = \frac{1000-850}{500} = 0.3.$$

The membership function of ENOUGH is

$$\mu_{enough}(x) = \begin{cases} 0, & x < 500, \\ \frac{x - 500}{500}, & 500 \le x < 1000, \\ \frac{1500 - x}{500}, & 1000 \le x < 1500, \\ 0, & x \ge 1500, \end{cases}$$

and

$$\mu_{enough}(850) = \frac{850-500}{500} = 0.7.$$

Therefore, road capacity can be said less with 30% membership function and the road capacity can be said to be enough with 70% membership function. Based on the rules according to the conditions, it is obtained:

Table 5: Table of Implication Function.

Green Light Duration		Road Capacity		
		Less	Enough	Surfeited
Volume of Vehicles	Smoothly	Fast (0.192)	Fast (0.192)	Fast (0.00)
	Effective	Fast (0.30)	Medium (0.70)	Medium (0.00)
	Dense	Medium (0.00)	Slow (0.00)	Slow (0.00)

So that the rules of green light duration are as follows:

[R1]. If the volume of vehicle is smoothly and the road capacity is less than the duration of the green light is fast.

$$\alpha_1 = \mu_{VolumeSMOOTHLY} \cap \mu_{Capacity\ LESS}$$
$$= min\,(\mu_{VolumeSMOOTHLY}(702), \mu_{Capacity\ LESS}(850)$$
$$= min\,(0.192,\ 0.30) = 0.192.$$

[R2]. If the volume of vehicle is smoothly and the road capacity is enough then the duration of the green light is fast.

$$\alpha_2 = \mu_{VolumeSMOOTHLY} \cap \mu_{Capacity\ ENOUGH}$$
$$= min\,(\mu_{VolumeSMOOTHLY}(702), \mu_{Capacity\ ENOUGH}(850))$$
$$= min\,(0.192,\ 0.70) = 0.192.$$

[R4]. If the volume of vehicle is effective and the road capacity is less than the duration of the green light is fast.

$$\alpha_4 = \mu_{VolumeEFFECTIVE} \cap \mu_{Capacity\ LESS}$$
$$= min\,(\mu_{VolumeEFFECTIVE}(702), \mu_{Capacity\ LESS}(850)$$
$$= min\,(0.808,\ 0.30) = 0.03.$$

[R5]. If the volume of vehicle is effective and the road capacity is enough then the duration of the green light is medium.

$$\alpha - predikat_5 = \mu_{VolumeEFFECTIVE} \cap \mu_{Capacity\ ENOUGH}$$
$$= min\,(\mu_{VolumeEFFECTIVE}(702), \mu_{Capacity\ ENOUGH}(850)$$
$$= min\,(0.808,\ 0.70) = 0.70$$

The composition of rules with the maximum function to find the fuzzy solution area is shown as follows:

$$\mu_{sf}[x] = \max\left(\mu_{kf_1}[x], \mu_{kf_2}[x], \mu_{kf_4}[x], \mu_{kf_5}[x]\right)$$
$$= \max\,(0.192, 0.30, 0.70).$$

Based on figure 3 and same manner, the solution is When $\mu_{durationMEDIUM}(a_1) = 0.30$, then the value of a_1 as follows:

$$\frac{a_1 - 10}{10} = 0.30,\ \ a_1 = 13.$$

When $\mu_{durationMEDIUM}(a_2) = 0.70$, then the value of a_2 as follows:

$$\frac{a_2 - 10}{10} = 0.70,\ \ a_2 = 17.$$

When $\mu_{durationMEDIUM}(a_3) = 0.70$, then the value of a_3 as follows:

$$\frac{30 - a_3}{10} = 0.70, \;\; a_3 = 23.$$

Thus, the membership function for the results of this composition is

$$\mu[z] = \begin{cases} 0.3, & z < 13, \\ \dfrac{z-13}{4}, & 13 \le z < 17, \\ 0.7, & 17 \le z < 23, \\ \dfrac{30-z}{7}, & 23 \le z < 30, \\ 0, & x \ge 30. \end{cases}$$

Defuzzification in determining the duration of the green light is by the centroid method. Moments for each region as follows:

$$\mathrm{M1} = \int_0^{13} 0.3z\, dz = 25.35;\ \mathrm{M2} = \int_{13}^{17} \left(\frac{z-13}{4}\right) z\, dz = 31.\overline{3};\ \mathrm{M3} = \int_{17}^{23} 0.7z\, dz = 84;\ \mathrm{M4} = \int_{23}^{30} \left(\frac{30-z}{7}\right) z\, dz = 88.\overline{6}$$

Then the area of each region as follows:

$$\mathrm{A1} = \int_0^{13} 0.3\, dz = 1.8;\ \mathrm{A2} = \int_{13}^{17} \left(\frac{z-13}{4}\right) dz = 2;\ \mathrm{A3} = \int_{17}^{23} 0.7\, dz = 4.2;\ \mathrm{A4} = \int_{23}^{30} \left(\frac{30-z}{7}\right) dz = 3.5$$

The center point (Castillo, 2008) obtained is

$$Z_0 = \frac{\int_0^{30} \mu_{(Z)}\, z\, dz}{\int_0^{7.5} \mu_{(Z)}\, dz}$$

$$Z_0 = \frac{M1 + M2 + M3 + M4}{A1 + A2 + A3 + A4}$$

$$= \frac{\int_0^{13} 0.3z\, dz + \int_{13}^{17} \left(\frac{z-13}{4}\right) z\, dz + \int_{17}^{23} 0.7z\, dz + \int_{23}^{30} \left(\frac{30-z}{7}\right) z\, dz}{\int_0^{13} 0.3\, dz + \int_{13}^{17} \left(\frac{z-13}{4}\right) dz + \int_{17}^{23} 0.7\, dz + \int_{23}^{30} \left(\frac{30-z}{7}\right) dz}$$

$$= \frac{25.35 + 31.\overline{3} + 84 + 88.\overline{6}}{1.8 + 2 + 4.2 + 3.5} = 16$$

So, the duration of the green light at the west leg in Sigura-gura Street is 16 seconds.

2.4.2 Determination of Green Light from East Cross Leg

The determination of the green light duration in the east leg using Mamdani method in fuzzy logic consists of the above four stages with volume of vehicles is 914 smp/hour and road capacity is 850 smp/hour. Formation of fuzzy set, application of implication function with MIN function, rule composition with MAX function, and defuzzification with centroid method obtained by output duration of green light from east leg Veteran Street is 28.1≈28 seconds.

2.4.3 Determination of Green Light from South Cross Leg

The determination of the green light duration in the south leg using Mamdani method in fuzzy logic consists of the above four stages with volume of vehicles is 948 smp/hour and road capacity is 1102 smp/hour. Formation of fuzzy set, application of implication function with MIN function, rule composition with MAX function, and defuzzification with centroid method obtained by output duration of green light from south leg Bend. Sutami Street is 29.7 ≈ 30 seconds.

3 CONCLUSIONS

The timing of the change of traffic light at the UB-ITN intersection from the Data of the Transportation Department of Malang City is still not effective to break down the traffic jam. Plot of vehicle volume data with duration of green light of the Transportation Department of Malang City is {(702, 24), (914, 22), (948, 31)}. So, for the leg intersection that large volume of vehicles has a shorter duration of green light, and vice versa. Therefore, once the traffic light control system is obtained, the duration of the green light is proportional. Plot the vehicle volume data with the duration of the green light of the traffic light control system is {(702, 16), (914, 28), (948, 30)}.

REFERENCES

Castillo, O. and Melin, P., 2008. *Type-2 Fuzzy Logic: Theory and Applications*. Springer, Berlin.

Hossain, Md. A., Shill, P. C., Sarker, B., and Murase, K., 2011. Optimal Fuzzy Model Construction with Statistical Information Using Genetic Algorithm.

International Journal of Computer Science & Information Technology (IJCSIT), 3 (6): 241-257.

Jang, J.S.R. et al. 1997. *Neuro-Fuzzy and Soft Computing.* London: Prentice Hall.

Lin, C. Teng & Lee, G. S. George, 1996. *Neural Fuzzy Systems.* London: Prentice Hall.

Mahalakshmi, P. and Ganesan, K., 2015. Mamdani Fuzzy Rule based Model to Classify Sites for Aquaculture Development. *Indian Journal of Fisheries*, 62 (1): 110-115.

Nguyen, Hung T, Prasad, N. R., Walker, C. L., and Walker, E. A., 2002. *A First Course in Fuzzy and Neural Control.* USA: Chapman & Hall/CRC.

Sumiati, Sigit, H. T., and Kapuji, A., 2014. Mamdani Fuzzy inference system Application Setting for Traffic Lights. *International Journal of Application or Innovation in Engineering & Management (IJAIEM)*, 3(10): 56-62