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Study of a Weather Prediction System Based on Fuzzy Logic Using Mamdani and Sugeno Methods

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Abstract

Weather is a very important factor in supporting various human activities. However, weather is a natural event that keeps on changing due to various air conditions that affect it. One way to anticipate weather changes that may occur early is to create a system that can predict weather changes. Fuzzy logic is one of the methods that can be used in system prediction to find out the cause at a certain time and place. In this system, two fuzzy logic methods were used, they are the Mamdani and Sugeno methods, with three supporting criteria, including air temperature, humidity, and air pressure. In this research, data levers were carried out in June 2022 and resulted in a percentage accuracy of 73.34% for the Mamdani method and 70% for the Sugeno method.

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INTRODUCTION

Technological developments require all aspects to take part in their use, including weather prediction. Weather is a very important factor in supporting various human activities. Uncertain weather will certainly affect human activities both personally and in groups. In such conditions, the weather prediction system can be used by humans to anticipate significant changes in weather that occur early. Indonesia is a tropical country as well as a maritime country, which means its weather conditions change significantly. Differences in geographical location also affect the weather in each region of Indonesia. In addition, changes in climate conditions that have increased dramatically have also caused changes in rainfall in Indonesia (Measey, 2010). Forecasting of Rainfall is an essential and significant method now a days. Every year, many people were died and banished due to heavy rain and floods (Janarthanan & Ramakrishnan, 2020).

Weather forecasting is one of the most important and demanding operational responsibilities carried out by meteorological services worldwide. It is a complicated procedure that includes numerous specialized technological fields (Rahman, 2020). The Meteorology, Climatology, and Geophysics Agency (BMKG) is an agency that provides information related to weather and climate in Indonesia. This institution establishes climatology stations in various places to observe environmental conditions around them. As a result, BMKG Indonesia, as an institution engaged in meteorology, climatology, and geophysics, is tasked with providing weather predictions in Indonesia based on existing data every day. But nowadays, it is very difficult to predict the weather with a simple prediction method quickly because global climate change causes atmospheric phenomena to change very quickly, which will make the change of seasons irregular and, basically, Indonesia has complexity in weather and climate phenomena.

With the advancement of science and technology to make it easier to predict weather based on meteorological data, a method was developed to predict weather conditions earlier using data from the BMKG Semarang Climatology Station, namely by building a weather prediction system based on fuzzy logic using the Mamdani method and Sugeno is based on three supporting criteria, namely air temperature, humidity, and air pressure (Wele *et al.,*2020).

Fuzzy logic itself is a logic that deals with the concept of partial truth, where classical logic states that everything can be expressed in binary (0 or 1) (Utnasari & Putria, 2021). The fuzzy system was first introduced by Prof. L. A. Zadeh of Barkelay in 1965. The fuzzy system is a structured and dynamic numerical estimator. This system has the ability to develop intelligence systems in an uncertain environment (Khayut *et al*, 2014). This system works by predicting a function with fuzzy logic (Saiful *et al*, 2015).

In fuzzy logic, there are three methods, namely the Mamdani, Sugeno, and Tsukamoto methods. In the Sugeno method, the reasoning is almost the same as the Mamdani method, but the output on Sugeno is not a fuzzy set but a constant or linear equation (Iqrom *et al*, 2022). In this study, the desired result is a weather prediction system based on fuzzy logic using the Mamdani and Sugeno methods that produces predictions close to the real data (observation results).

METHODS

The data used are surface climate observations obtained from the Semarang Climatology Station with a geographical position of 6° 59' 4" South Latitude and 110° 22' 52" East Longitude with a height above sea level of ±6 meters. Data from surface weather observations includes data on average air temperature, humidity, air pressure, and weather. The data used is daily data for June 2022. The general stages of the weather prediction system are shown in the flow chart for making the following weather prediction model:

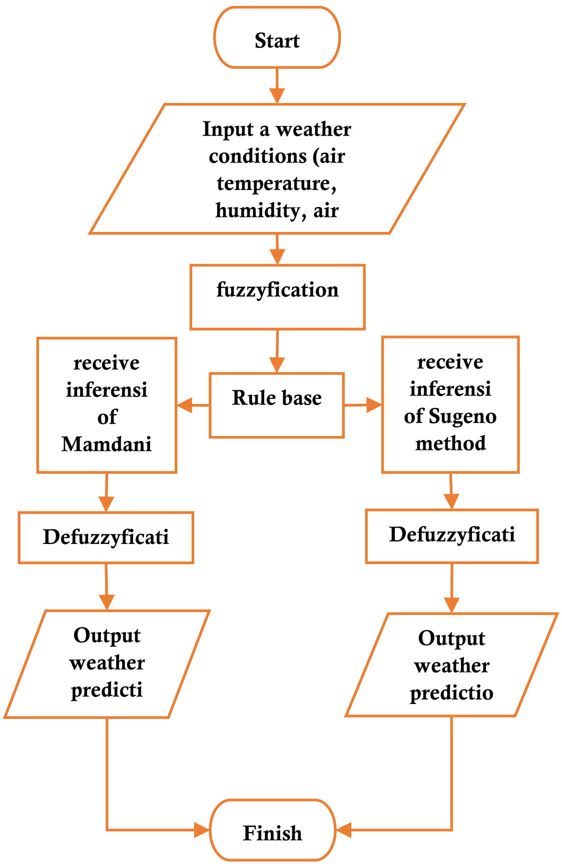


Figure 1. Weather Prediction Flowchart

RESULT AND DISCUSSION

In this weather prediction system, there are input variables consisting of air temperature, humidity, and air pressure. Meanwhile, the output variables are rainfall and weather predictions. Based on reference data that has been obtained from BMKG Climatology Station Semarang City, fuzzy sets can be formed as seen in Table 1 and Table 2:

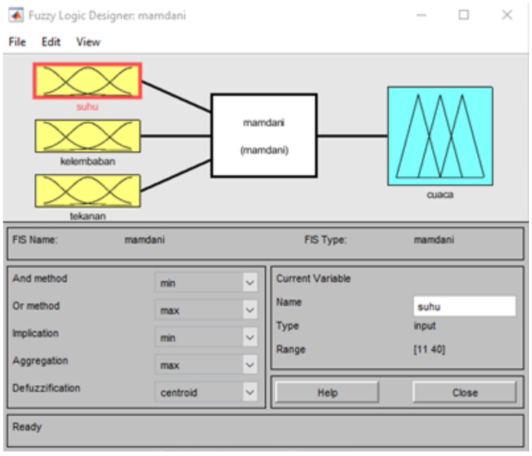
Table 1. Fuzzy Logic Input Set

Variable	Fuzzy sets	Range	Domain
Air Temperature (°c)	Cold	[11-40]	[11-21]
	Warm_1		[20-27]
	Warm _2		[26-28]
	Warm _3		[27-31]
	Hot		[30-40]
Humidity (%)	Dry	[30-100]	[30-41]
	Humid _1		[40-71]
	Humid _2		[70-80]
	Humid_3		[79-89]
	Wet		[88-100]
Air Pressure (mb)	Low	[980-1014]	[980-1007]
	Medium		[1006-1007]
	High		[1008-1014]

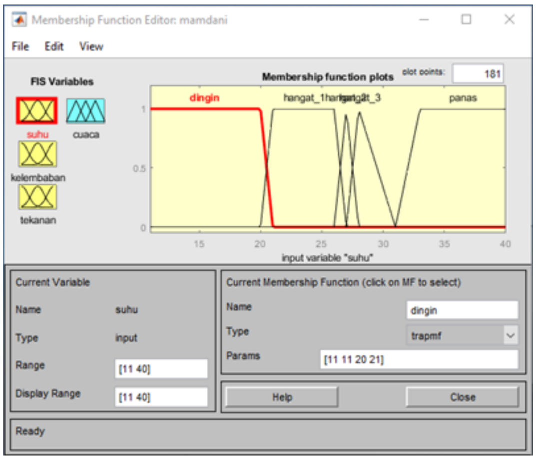
Table 2. Fuzzy Logic Output Set

Variable	Fuzzy sets	Range	Domain
Rainfall changes (mm)	No Rain or Sunny	[0-150]	[0-0,5]
	Light Rain		[0,5-20]
	Moderate Rain		[20-50]
	Heavy Rain		[50-100]
	Very Heavy Rain		[100-150]

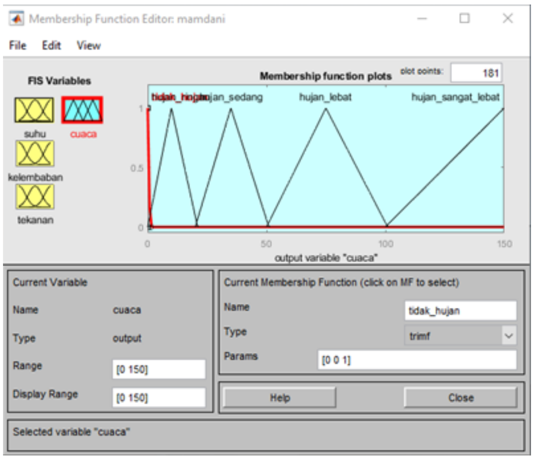
Based on the set of fuzzy logic that has been determined in Table 1 and Table 2, the curve of each variable Fuzzy Inference System (FIS) is shown in Figure 2.



(a)



(b)



(c)

Figure 2. The curves of each variable (a) FIS Mamdani Method Editor, (b) Fuzzy Logic Input Set, (c) Fuzzy Logic Output Set

All algorithms are created in the Rule Editor by using the operand and determining the predictive value. The rule bases are shown in Figure 3.

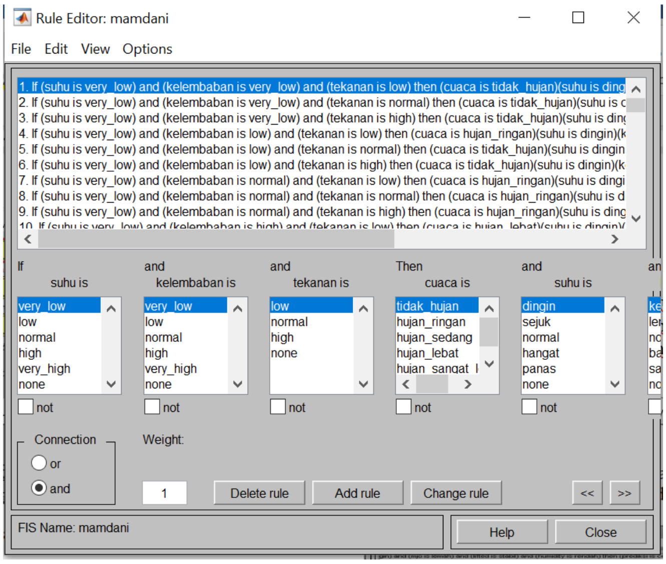


Figure 3. Rule Editor

The algorithm created in the rule editor can be visualized using the Rule Viewer that shown in Figure 4, where changing the values of the input variables will get the output variable values.

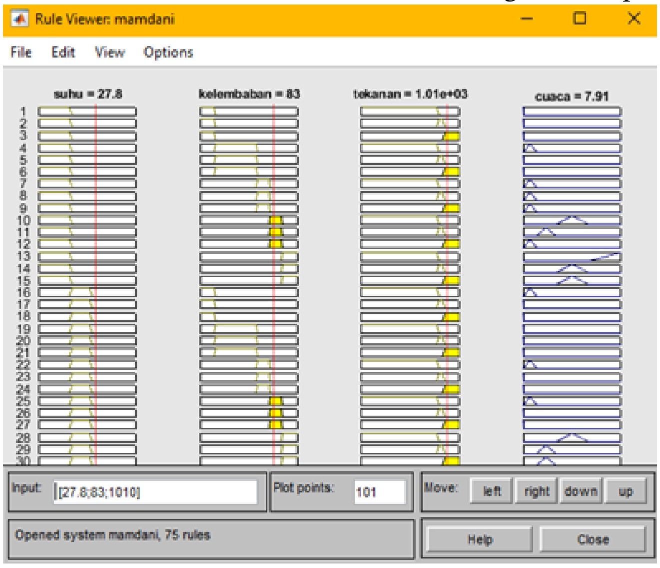


Figure 4. Rule Viewer Mamdani Method

The Sugeno type FIS that shown in Figure 5 and Figure 6, which has a display in the FIS Editor, is almost similar to the Mamdani type. The difference is from the output variable and the inactivity of selecting the type of function for implication and aggregation.

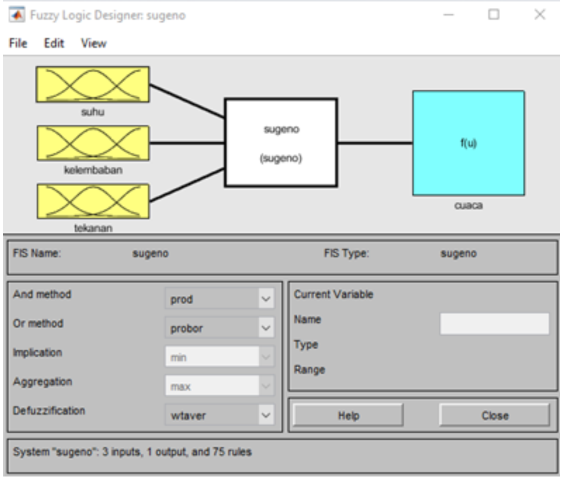


Figure 5. FIS Sugeno Method Editor

Even though the input variables of both types are the same, the membership function at the output of Sugeno can be linear and constant. In this study, an output with a constant value was selected.

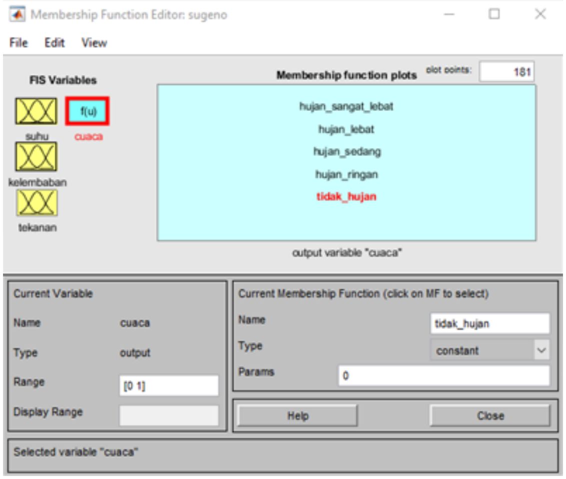


Figure 6. Sugeno Method Output Set

The next stage is to integrate the two FIS-files, Mamdani and Sugeno, into a Graphic User Interface (GUI) in Figure 7. The purpose of making a GUI is to make it easier for users to enter input when making weather predictions by specifying the desired input parameters.

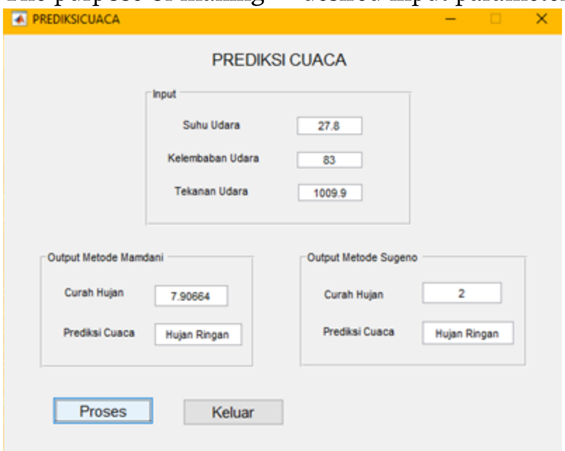


Figure 7. Weather Prediction GUI

The weather prediction model with fuzzy logic uses three input variables in the form of air temperature, humidity, and air pressure as well as 75 rules that will produce weather predictions, namely no rain or sunny, light rain, moderate rain, heavy rain, very heavy rain, and extreme rain.

The output display of the Weather Prediction GUI is shown in Figure 7. It can be seen that there are similarities between the results of the FIS evaluation for fuzzy logic using the Mamdani and Sugeno methods, with the same input parameters and categories. An example of a forecast model that can be seen in Figure 7. By entering the input values of temperature of 27.8º, humidity of 83%, and air pressure of 1009.9 mb, the fuzzy output value of weather is 7.9 in the Mamdani method, and the weather output is worth 2 in the Sugeno method. Both weather output values are included in the prediction of light rain.

After compiling the model as shown in Figure 2, the data input is carried out in June 2022, which is as much as 30 data points. The prediction results are then verified with the actual weather conditions. Verification is done by comparing the prediction results with the actual weather conditions (observation data). Verification is the process of determining the accuracy of the model's implementation. The most important part in model development is verification, and the model can be accepted and used to support decision making.

Table 3. Verify the Daily Weather Prediction for June 2022

Day	Air Temperature (°C)	Humidity (%)	Air Pressure (mb)	BMKG		Mamdani Method		Sugeno Method	
				Rainfall Changes (mm)	Linguistic Variable	Rainfall Changes (mm)	Linguistic Variable	Rainfall Changes (mm)	Linguistic Variable
1	28.4	79	1009.2	0	No Rain/Sunny	0	No Rain/Sunny	0	No Rain/Sunny
2	28.5	79	1008.9	0	No Rain/Sunny	0	No Rain/Sunny	0	No Rain/Sunny
3	27.8	83	1009.9	3	Light Rain	7.9	Light Rain	2	Light Rain
4	27.9	81	1010.5	3	Light Rain	6.2	Light Rain	1	Light Rain
5	26.9	84	1009.6	0	No Rain/Sunny	10.1	Light Rain	9	Light Rain
6	26.3	89	1008.8	49	Moderate Rain	29.3	Moderate Rain	25.1	Moderate Rain
7	27.7	80	1008.7	16	Light Rain	8.6	Light Rain	3	Light Rain
8	28.2	80	1009.5	0	No Rain/Sunny	0	No Rain/Sunny	0	No Rain/Sunny
9	27.6	81	1008.6	0	No Rain/Sunny	9.19	Light Rain	4	Light Rain
10	28.8	75	1008.9	0	No Rain/Sunny	0	No Rain/Sunny	0	No Rain/Sunny
11	28.7	79	1009.3	0	No Rain/Sunny	0	No Rain/Sunny	0	No Rain/Sunny
12	27.9	82	1010.2	32	Moderate Rain	6.2	Light Rain	1	Light Rain
13	27.5	83	1010.2	31	Moderate Rain	9.48	Light Rain	5	Light Rain
14	28.3	77	1009.9	0	No Rain/Sunny	0	No Rain/Sunny	0	No Rain/Sunny
15	28.5	77	1010.0	0	No Rain/Sunny	0	No Rain/Sunny	0	No Rain/Sunny
16	28.5	76	1010.9	0	No Rain/Sunny	0	No Rain/Sunny	0	No Rain/Sunny
17	27.7	80	1009.7	2	Light Rain	8.69	Light Rain	3	Light Rain
18	27.1	82	1010.3	1	Light Rain	10.18	Light Rain	9	Light Rain
19	26.8	87	1010.3	0	No Rain/Sunny	10.04	Light Rain	8	Light Rain
20	28.4	78	1009.0	4	Light Rain	0	No Rain/Sunny	0	No Rain/Sunny
21	27.8	82	1008.8	6	Light Rain	7.9	Light Rain	2	Light Rain
22	28.9	72	1009.9	0	No Rain/Sunny	0	No Rain/Sunny	0	No Rain/Sunny
23	27.1	79	1010.8	0	No Rain/Sunny	0	No Rain/Sunny	0	No Rain/Sunny
24	27.5	81	1009.7	3	Light Rain	9.48	Light Rain	5	Light Rain
25	27.3	82	1009.3	0	No Rain/Sunny	9.89	Light Rain	7	Light Rain
26	26.6	89	1009.5	40	Moderate Rain	32.43	Moderate Rain	14	Light Rain
27	27.2	87	1010.2	7	Light Rain	10.04	Light Rain	8	Light Rain
28	27.6	78	1009.7	35	Moderate Rain	0	No Rain/Sunny	0	No Rain/Sunny
29	28.3	64	1008.0	0	No Rain/Sunny	0	No Rain/Sunny	0	No Rain/Sunny
30	26.5	73	1008.6	0	No Rain/Sunny	0	No Rain/Sunny	0	No Rain/Sunny

Based on Table 3, the results of the daily weather prediction in June 2022 using the fuzzy logic of the Mamdani method show 22 exact data points from 30 available data points based on linguistic variables. Therefore, the percentage accuracy of the fuzzy inference system with the Mamdani method is 73.34%. Meanwhile, the Sugeno method shows 21 exact data points from 30 available data points based on linguistic variables. Then the percentage accuracy of the fuzzy inference system with the Sugeno method is 70%. This shows that the weather prediction system using fuzzy logic with the Mamdani method has a greater percentage of accuracy compared to the Sugeno method.

Therefore, the fuzzy logic-based weather prediction system using the Mamdani method can be said to be better than the fuzzy logic-based weather prediction system using the Sugeno method. However, the two methods used are equally bad at predicting rainfall. Based on Table 3. the results of the rainfall prediction using the Mamdani and Sugeno methods are only able to give approximate results for the actual intensity (Linguistic Variable).

The most important factor in the formation of fuzzy logic models is the formation of basic rules, or rule bases. The rule base itself is based on the rain pattern that occurred in June 2022. When the weather conditions are not rainy or clear, it is easier to determine compared to other weather conditions. This is in line with the view of meteorology, where determining sunny weather is easier than determining rainy weather conditions. This can be seen when the data shows the weather has a certain rainfall. This fuzzy logic-based weather prediction system is still not good at determining the intensity of rainfall using both the Mamdani method and the Sugeno method of fuzzy logic.

In addition, in this study, only three supporting criteria were used, namely air temperature, humidity and air pressure, where the three criteria are still less complex in making a weather prediction system. There are still many factors that must be taken into account in developing a weather prediction system so that the predictions produced are accurate.

CONCLUSION

Based on the research conducted, namely the initial study of fuzzy logic-based weather systems using the Mamdani and Sugeno methods, it can be said that the application of fuzzy logic to predict weather in Semarang has been made using two fuzzy prediction methods, namely the Mamdani method and the Sugeno method. The results of the June 2022 data lever for the Mamdani method have a current accuracy of 73.34% and the Sugeno method has a current accuracy of 70%, so it can be said that the fuzzy logic system with the Mamdani method is better for determining the daily weather in Semarang. However, the fuzzy logic system is still not good at determining rainfall predictions and is only able to provide approximate results with actual data (Linguistic Variable). It needs to be done again to estimate the amount of rainfall by multiplying the variables used to produce accurate output.

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REFERENCES

Arifin, S, Muslim, M.A., & Sugiman. (2015). Implementasi Logika Fuzzy Mamdani Untuk Mendeteksi Kerentanan Daerah Banjir di Semarang Utara. *Scientific Jurnal of Informatics 2*(2).

Iqrom, Amri, F., Sinaga, B.N., & Pambudi, S. (2022). Analisis Perbandingan Metode Sugeno dan Mamdani (Studi Kasus: Sistem Tingkat Curah Hujan di DKI Jakarta). *BISIK: Jurnal Ilmu Koputer, Hukum, Kesehatan, dan SosHum, 1*(1).

Janarthanan, R. & Ramakrishnan, B. (2020). *Prediction of rainfall using fuzzy logic*. Materials Today: Proceedings. DOI: 10.1016/j.matpr.2020.06.179

Khayut, B., Fabri, L., & Abukhana, M. (2014). *Inteligent Multi-Agent Fuzzy Control System Under Uncertainty*. Proceeding of International conference on Foundation of Computer Science & Technology, 2-4 January 2014. Zurich, Switzerland.

Measey, M. (2010) Indonesia: A Vulnerable Country in the Face of Climate Change. *Global Majority E-Journal, 1*(1) 31-45.

Rahman, M. A. (2020). Improvement of Rainfall Prediction Model by Using Fuzzy Logic. *American Journal of Climate Change 9*, 391-399.

Utnasari, I. & Putria, N.E. (2021). Weather Determination Prediction Using Expert Fuzzy Logic Mamdani Method. IJISTECH (*International Journal of Information System &*

Technology) *5*(4), 518-525. https://doi.org/10.30645/ijistech.v5i4.172

Wele, I.H., Rumlaklak, N.D., & Boru, M. (2020). Sistem Peramalan Cuaca Dengan Fuzzy Mamdani (Studi Kasus: BMKG Lasiana). *J-ICON: Jurnal Komputer Dan Informatika*, 8(2), 163-169. https://doi.org/10.35508/jicon.v8i2.2883