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Comparative Analysis using Tsukamoto and Sugeno Methods of Fuzzy Inference System for Sales of Medicine

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Abstract: This case study has been implemented on the apothecary shop located at Kotabumi city at Lampung province, Indonesia that selling various types of medicine. An apothecary in his scientific efforts need by prediction to a hypothetical for determining the amount of in the demand and the purchase of the new term, which has a challenge on increasing the purchasing amount and reflected the bank sound assets. A prediction used was to analyzed from the results of the comparison a method of Tsukamoto and Sugeno by using the nine rules and comparison to the value of absolute error of the purchase. Based on a the Sugeno method, the absolute error of the purchase was 0.0176 %, which is the lowest value in the study.

Keywords: purchasing prediction, fuzzy inference, absolute error

1. Introduction

Pharmacy is shops sell various medicine and medical equipment. In accordance with their medicine and due to the climate changes in Indonesia, it is currently having a high demand on some antibiotic medicines. Numerous types of an antibiotic in the business process to predict the determining and the purchase amount of medicine at the next period. This research using a comparison of the two prediction methods, i.e., the Tsukamoto and the Sugeno methods to predict the purchasing profile of antibiotic medicines in the pharmacy. The two methods were using a standard of fuzzy inference system for energy savings-and-loan, that also proposed elsewhere [1]. The fuzzy logic and fuzzy set theory deal with non-probabilistic uncertainties issues.

The fuzzy control system is based on the theory of fuzzy sets and fuzzy logic. Previously a large number of fuzzy inference systems and defuzzification techniques were reported. These systems/techniques with less computational overhead are useful to obtain crisp output [2]. The crisp output values are based on linguistic rules applied in inference engine and defuzzification techniques [2]. The existing fuzzy models have addressed the way to reason using membership function and fuzzy rule but did not take into account the time dependency of output in the control systems [2,3].

2. Materials and Methods

2.1. Fuzzy

The fuzzy theory was first introduced by Dr. Lotfi Zadeh in 1965 to develop qualitative concept that has no precise boundaries [3]. The application of fuzzy method then become more popular and implemented in some other field, as for example to define the value that represents the boundary between normal and low, normal or high condition of some cases. Fuzzy logic then becoming an appropriate solution that similar to the black box in order to find a solution and the output value of some specific cases in engineering [4].

Fuzzy logic is mainly based on the systems that are classified according to the types of the input rules of fuzzy definition. The three major types of fuzzy rules, they are including the Mamdani type, Takagi-Sugeno-Kang type (TSK model), and Tsukamoto type [5]. The Mamdani type is using the following format rules:

$$R_k : \text{If } [x_1 \text{ is } A_{1k}] \text{and } [x_2 \text{ is } A_{2k}] \text{and} \cdots\cdots \text{and} [x_n \text{ is } A_{nk}] \text{ then } [y \text{ is } B_k] \quad (1)$$

where Rk is the k-th rule in the fuzzy rule base system and (k = 1,2,..,k). The Ajk and Bk are the value of fuzzy sets based on the appropriate domains (j = 1,2,..n) [6]. While the Takagi-Sugeno-Kang type was using the following format rule:

$$R_k : \text{If } [x_1 \text{ is } A_{1k}] \text{and } [x_2 \text{ is } A_{2k}] \text{and} \cdots\cdots \text{and} [x_n \text{ is } A_{nk}] \text{ then } y = f(x_1, x_2, \ldots, x_n) \quad (2)$$

where Rk, Ajk and Bk have the same meaning as on Madani type, while y = f (x1, x2, ..., xn) is a real-valued function of n the same variables as Mamdani-type. The fuzzy sets of Bk appearing in the consequent to have profiles that are based on the setting for a monotonic increasing or decreasing trend [5].

This study using a fuzzy inference system with the specifications are the room Temperature variable divided into four sets, which are:

- request for at least = 630 and demand for most = 900
- supplies at least = 0 and supplies most = 200
- reservation at least = 600 and reservations for most = 900.

2.2. Fuzzification

The modelling of this fuzzifications is including the following rules:

1. The request (x)

Request at least[x] max = ((reservations for most – reservation at least) x 0,5 + Request at least) = ((900 – 630) x 0,5 +630) = 765
μ Request at least[x] max = 630
μ Request at middle [x] max = ((demand for most – Request at least) x 0,75 + Request at least) = ((900 – 630) x 0,75 + 630) = 832,5
μ Request at middle [x] max = ((Request max – Request min) x 0,25 + Request min) = ((900 – 630) x 0,25 + 630) = 697,5
μ Request max [x] max = 900

The rules are represented on Fig. 1.

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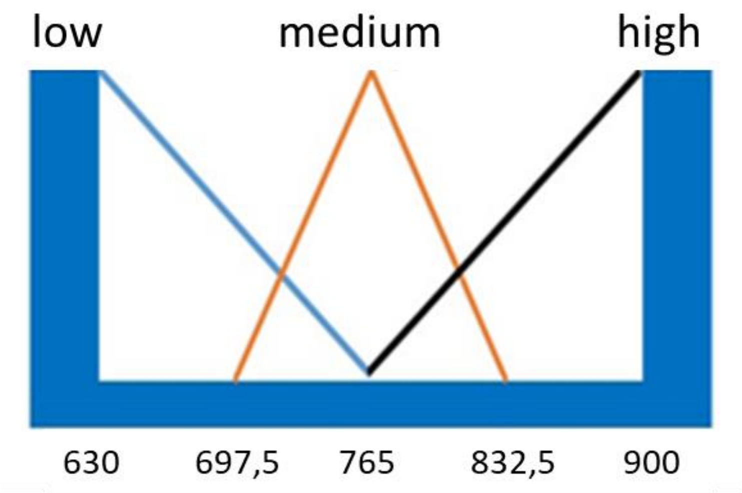

Figure 1. Charts the functional variable request (x)

µ Request max [x] min = ((Request max – Request min) x 0,5 + Request min) = ((900 – 630) x 0,5 + 630) = 765, as follow:

$$\mu \text{ Request min } [x] \begin{cases} 0, & x \geq 765 \\ \frac{765-x}{765-630}, & 630 < x < 765 \\ 1, & x \leq 630 \end{cases}$$

$$\mu \text{ Request demand } [x] \begin{cases} 0, & x \geq 832{,}5 \text{ dan } x \leq 697{,}5 \\ \frac{x-697{,}5}{765-697{,}5}, & 697{,}5 < x < 765 \\ \frac{832{,}5-x}{832{,}5-765}, & 765 < x < 832{,}5 \\ 1, & x = 765 \end{cases}$$

$$\mu \text{ Request max } [x] \begin{cases} 0, & x \leq 765 \\ \frac{x-765}{900-765}, & 765 < x < 900 \\ 1, & x \geq 900 \end{cases}$$

2. The supplies (y)

µ supplies at least [y] max = ((supplies max – supplies min) x 0,5 + supplies min) = ((200 – 0) x 0,5 + 0) = 100
µ supplies min [y] min = 0
µ supplies demand[y] max = ((supplies max – supplies min) x 0,75 + supplies min) = ((200 – 0) x 0,75 + 0) = 150
µ supplies demand[y] min = ((supplies max – supplies min) x0,25 + supplies min) = ((200 – 0) x 0,25 + 0) = 50
µ supplies max[y] max= 200
µ supplies max [y] min = ((supplies max – supplies min) x 0,5 + supplies min) = ((200 – 0) x 0,5 + 0) = 100, as represented on Fig. 2 and the following calculation below.

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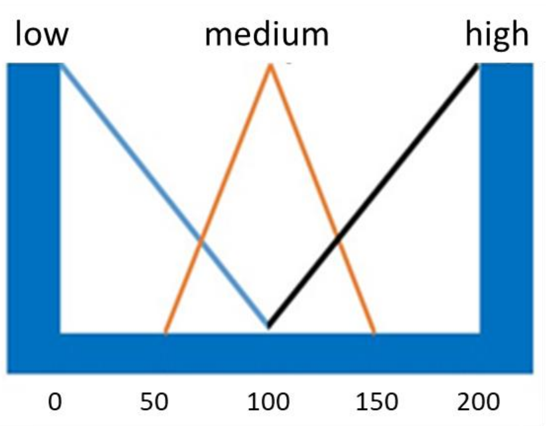

Figure 2. Charts the functional variable request (y)

$$\mu \text{ supplies min } [y] \begin{cases} 0, & y \geq 100 \\ \frac{100-y}{100-0}, & 0 < y < 100 \\ 1, & x \leq 0 \end{cases}$$

$$\mu \text{ supplies demand } [y] \begin{cases} 0, & y \geq 150 \text{ dan } y \leq 0 \\ \frac{y-50}{100-50}, & 50 < y < 100 \\ \frac{150-y}{150-100}, & 100 < y < 150 \\ 1, & y = 100 \end{cases}$$

$$\mu \text{ supplies max } [y] \begin{cases} 0, & y \leq 100 \\ \frac{y-100}{200-100}, & 100 < y < 200 \\ 1, & y \geq 200 \end{cases}$$

3. The purchasing and reservation (z)

μ reservation at least [z] max = ((reservation max – reservation at least) x 0,5 + reservation at least) = ((900 – 600) x 0,5 + 600) = 750 μ reservation at least [z] min = 600

μ reservation at demand [z] max = ((reservation max – reservation at least) x 0,75 + reservation at least) = ((900 – 600) x 0,75 + 600) = 825

μ reservation at demand [z] min = ((reservation max – reservation min) x 0,25 + reservation min) = ((900 – 600) x 0,25 + 600) = 675

μ reservation max[z] max = 900 μ reservation max [z] min = ((reservation max – reservation min) x 0,5 + reservation min) = ((900 – 600) x 0,5 + 600) = 750, as presented in Fig. 3 and the following equations below.

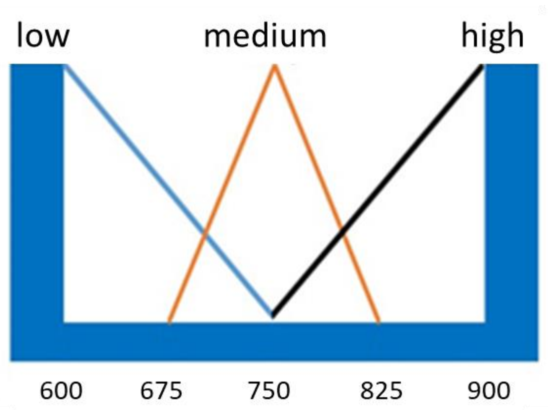

Figure 3. Charts the functional variable reservations ~ (z)

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$$\mu \text{ reservation min}[z] \begin{cases} 0, & z \geq 750 \\ \frac{750-z}{750-600}, & 600 < z < 750 \\ 1, & z \leq 600 \end{cases}$$

$$\mu \text{ reservation at demand}[z] \begin{cases} 0, & z \geq 825 \text{ dan } z \leq 675 \\ \frac{x-675}{750-675}, & 675 < z < 750 \\ \frac{825-z}{825-750}, & 750 < z < 825 \\ 1, & z = 750 \end{cases}$$

$$\mu \text{ reservation max}[z] \begin{cases} 0, & z \leq 700 \\ \frac{z-750}{900-750}, & 750 < z < 900 \\ 1, & z \geq 900 \end{cases}$$

4. Counting value membership demand

μ Request min [x]= Adapted to the rule's membership

μ Request at middle[x]= adapted to the rule's membership. μ Request max[x] = Adapted to the rule's membership.

5. Counting the value of membership of the supplies

μ supplies min[y]= adapted to the rule's membership.

μ supplies at demand[y]= adapted to the rule's membership.

μ supplies at demand[y]= adapted to the rule's membership.

6. The implications of Tsukamoto's method

[R1] if request min and the supplies min, then reservation min, as follow:

A-predicate1=min(μ request min [X]; μ supplies min [Y]), by us the function of reservation's takes all item into the following calculation:

(750-Z)/(750-600)= A-predicate1 ; Z1=750-(A-predicate1*(750-600))

[R2] if request min and supplies middle, then the reservation min, as follow:

α-predikat2=min x (μ Request min [x]; μ supplies middle [y])

By using the function of little force, the prediction of the ticket selling is as the following equation. At low condition, (750-z)/(750-600)= α-predicate2 ; Z2=750-(α-predicate2*(750-600))

[R3] if the request min and supplies max, then the reservation min α-predicate3=min (μ request min [x]; μ supplies max [y]).

Using the function of reservation, it may be taken into the following equation:

(750-z) / (750-600) = α-predicate3; Z3=750-(α-predicate3*(750-600))

[R4] if the request at middle and supplies min, then the reservation middle α-predikat4 = min (μ request middle [x]; μ supplies min [y]).

Using the function of reservations, it will be taken into the following equation:

(z-675) / (750-675) = α-predicate4; Z4=675-(α-predicate4*(750-675))

[R5] if the request in the middle and the supplies also in the middle, then the reservation in the middle as follow:

α-predicate5 = min (μ Request middle [x]; μ request middle [y]).

Using the function of reservations, it will be taken into the following equation:
(z-675) / (750-675) = α-predicate5; Z5=675-(α-predicate5*(750-675))

[R6] if the request in the middle and the supplies at maximum condition, and the reservation in the middle, it can be calculated as follow:
α-predicate6 = min (μ request middle [x]; μ supplies max [y]).

By using the function of reservations, it will be taken into the following equation:
(z-675) / (750-675) = α-predicate6; Z6=675-(α-predicate6*(750-675))

[R7] if the request at maximum condition, the supplies in minimum, then the reservation maximum, it can be calculated as follow:
α-predicate7 = min (μ request max [x]; μ supplies min [y])

Using the function of reservations, then it can be calculated as follow:
(z-750) / (900-750) = α-predicate7; Z7=750-(α-predicate7*(900-750))

[R8] if the request maximum and supplies in the middle, then the reservation maximum, can be calculated as follow:
α-predikcate8 = min (μ reservation max [x]; μ supplies middle [y])

By using the function of reservations enough, then it can be calculated as follow:
(z-750) / (900-750) = α-predicate8; Z8=750-(α-predikat8*(900-750))

[R9] if the request max and the supplies max, then the reservation max, the equation will be as follow:
α-predikcate7 = min (μ request max [x]; μ supplies max [y])

By using the function of reservations enough, it can be formed as follow:
(z-750) / (900-750) = α-predicate9; 9 = 750 - (α-predicate9*(900-750)).

2.2. The Implications to Sugeno method

By the use of function of the reservation it may be calculated the implication by using Sugeno method, with the constant consequent, that may be calculated as follow:

[R1] if request min and supplies min, then the reservation min, as follow:
α-predicate1 = min (μ request min [x]; μ supplies min [y])
The value of z1 = x-y

[R2] if the request min and the supplies middle, then the reservation min, can be calculated as request minus supplies, as follow:
α-predicate2 = min (μ Request min [x]; μ supplies middle [y])
The value of z2= x-y

[R3] if the request min and the supplies max, then the reservation min, it can be calculated as follow:
α-predicate3 = min (μ Request min [x]; μ supplies max [y])
The value of z3= x-y

[R4] if the request in the middle, the supplies min then the reservation middle, the request – supplies was the following equation:

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α-predicate4 = min (μ Request middle [x]; μ supplies min [y]).
The value of z4= x-y

[R5] if the request is in the middle, the supplies also in the middle, then the reservation also in the middle, the request – supplies was the following equation:
α-predicate5 = min (μ Request middle [x]; μ Request middle [y])
The value of z5= x-y

[R6] if the request is in the middle, the supplies at maximum, then the reservation in the middle, then the request – supplies is as follow:
α-predicate6 = min (μ Request middle [x]; μ supplies max [y])
The value of z6= x-y

[R7] if the request is maximum, the supplies is minimum, then the reservation in the maximum, the request – supplies is as follow:
α-predicate7 = min (μ request max [x]; μ supplies min [y]).
The value of z7= x-y

[R8] if the request is maximum, the supplies in the middle, then the reservation at the maximum stage, the request – supplies was as follow:
α-predicate8 = min (μ reservation max [x]; μ supplies middle [y])
The value of z8= x-y

[R9] if the request at maximum, the supplies maximum, then the reservation maximum, the request-supplies will be as follow:
α-predicate9 = min (μ request max [x]; μ supplies max [y])
The value of z9= x-y.

The calculations based on the Tsukamoto method is as in the following equation:

$$Z = \frac{\sum a1.Z1}{\sum a1} \quad (3)$$

Z=((0*750)+(0,852*622,2)+(0*750)+(0*675)+(0*675)+(0*675)+(0*750)+(0*075)+(0*750))
/(0+0,852+0+0+0+0+0+0+0)
Z=(530,1144) / (0,852) Z=622,2

While the calculations based on the Sugeno method is as follow:

$$Z = \frac{\sum a1.Z1}{\sum a1} \quad (4)$$

Z=((0*550)+(0,852*550)+(0*550)+(0*550)+(0*550)+(0*550)+(0*550)+(0*550)+(0*550))
/(0+0,852+0+0+0+0+0+0+0) Z=(468,6)/(0,852)
Z=550

So, in the prediction on the further month by the real data from the pharmacy can be calculated for the prediction by using the methods either with Tsukamoto that equal to 622,2. While using the Sugeno method is equal to 550. The percentage of error from both prediction methods can be calculated as follows way:

$$\frac{|(\text{supplies} + \text{prediction}) - \text{request}|}{\text{request}} \text{ X } 100\%$$

The error presentation using Tsukamoto method is as follow:

$$\frac{|(100 + 622{,}2) - 650|}{650} \text{ X } 100\%$$

While the error presentation using Sugeno method is as follow:

$$\frac{|(100 + 550) - 650|}{650} \text{ X } 100\%$$

The equation above will be used for the calculation for the purchasing power prediction during the whole year based on the data resources as on Table 1.

Table 1. Percent error of every month

Month	Total error predicted		The large number o the prediction to a hypothese
	Tsukamoto	Sugeno	4
February	0,321765	0	4
March	0,426697	0	4
April	2,846921	0,419048	4
May	2,125174	0	4
June	12,949482	0	4
July	0,158233	0	5
August	3,744986	0,408266	4
September	0,614468	0	4
October	N/A	0,448658	4
November	N/A	0,269407	4
December	N/A	0,112231	5

Based on the data resource on Table 1, it can be calculated the average absolute of the error for the whole year of sales. The average absolute percentage of error from the results using the prediction of Tsukamoto method is as follow:

$$\frac{\Sigma \text{ percent of error}}{\text{total prediction}} = \frac{23{,}701557}{47} = 0{,}504288\ \%$$

While the average absolute percentage of error from the results using the prediction of Sugeno method is as follow:

$$\frac{\Sigma \text{ percent of error}}{\text{total prediction}} = \frac{0{,}827346}{47} = 0{,}017602\ \%$$

Based on above equations, it can be seen that the result from calculation of average absolute error by using the different prediction methods may resulted different value, as also presented on the other results [5,6].

3. Conclusions

Based on the results from the prediction reservations of the medicines in the pharmacy shop using the fuzzy inference method of Tsukamoto and Sugeno referring to data real purchasing data from the previous year, the purchasing power during the following years may be predicted. In this study, it is founded that the absolute error of Tsukamoto method resulting a greater value of 0,504288% once compare to the Sugeno method of 0,0176%. This finding may be suggested for the same business type of pharmacy shop may be using the Sugeno method for the prediction of purchasing power.

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