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Application Of Fuzzy Inference System By Sugeno Method On Estimating Of Salt Production

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Abstract. Salt is one of the most important needs in everyday life. Making traditional salt largely is done by smallholder farmers in addition by manufacturers of industrial salt. factors that affect the production of salt include seawater, soil, water influence and weather conditions including rainfall wind speed and solar radiation or long dry erratic, these conditions obviously affect the salt farmers that will affect the production quantities of salt produced by salt farmers. In this study, the fuzzy logic method is applied to Sugeno fuzzy inference systems to estimate the production of salt by variables - variables that affect it. This study aims to estimate how much production by applying fuzzy inference systems zero-order Sugeno method based on the variable wind speed, solar radiation, rainfall and the amount of production. Retrieval of data obtained from the Air Quality Meteorology and Geophysics. salt farmers in Pamekasan District of Pademawu Village Majungan. Data taken within 2 years per week from June to December of 2014 and 2015. The Sugeno fuzzy logic model in this study using output (consequent) in the form of equation constants (Sugeno models Order zero). Apparently from the research results obtained by the error value most low at 0.0917, so it can be said to be close to zero. Keyword : production number, zero-order Sugeno method, salt.

INTRODUCTION

Based on Afonso (2014) that Indonesia as an archipelagic country with a long coastline of 81,000 km is the coastal areas and oceans that have a variety of biological resources and non-biological enormous. With the sea which is 70% of the total area of the country, the sea a lot of potential to be used, among others, is salt. Salt than as herbs are also a raw material in many industrial processes, including the manufacture Sodium Sulfate (Na2SO4), soda ash (Na2CO3), Sodium Bicarbonate (NaHCO3) and others. During these salts are used as cooking ingredients in the household, and therefore the processing is still simple standard or traditional. Besides that, based on Setyaningrum et al (2014) that manufacture of traditional salt, made by leveling the ponds using tools drawn steel cylinder manpower. After it was filled with sea water and with the help of sunlight and sea water into droplets crystallize grain of salt. Based on Adi (2006) that Constraints faced by salt farmers in Pamekasan as a decline in production resulting from the factors that influence the production of salt include seawater, soil, water influence and weather conditions including rainfall wind speed and solar radiation or long dry erratic, the condition obviously affects the salt farmers that will affect the production quantities of salt produced by salt farmers.

Related to these problems, it is necessary to estimate the amount of research in the production of salt farmer which will be processed to be salt industries by using fuzzy logic. Based on Sudjianto (2007) that result of research is shown the material stabilization of NaCl can be stabilizasi of behaviour fisic and mechanic expansive soil. Mix design is very good as 50% add NaCl. Based on Setyaningrum et al (2014) that Fuzzy logic is the study of the uncertainty which has the advantages of capability in the process of reasoning in the language (linguistic reasoning). In the theory of fuzzy logic known a fuzzy system concepts used in the prediction process and generally consists of four stages: fuzzification, the formation of fuzzy rules, inference systems / fuzzy reasoning and defuzzification. Fuzzy inference method that is

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generally used is Mamdani, Sugeno and Tsukamoto. But in this study fuzzy inference method used is the zero-order Sugeno method because this method antecedent represented by the rules in the fuzzy set, while the consequence is represented by a constant.

The problem in this research is how the application system Sugeno fuzzy inference method in determining the approximate amount of salt farmers by variable wind speed, solar radiation, rainfall and the amount of production. This research aims to create a system of fuzzy inference zero-order Sugeno method that can be used to estimate the number of simulation models of production and making FIS Sugeno method using matlab.

DEFINITION OF SALT

Based on Adi (2006) Salts can be divided into two types based on their functions, namely salt consumption and industrial salt. Salt consumption is used for domestic consumption and food industries. Industrial salt used for the petroleum industry, the manufacture of soda and chlorine, leather tanning, and medicine. The salt is circulated nationally the majority do not have a qualified iodized.

Based on Afons (2014) Salt is a white solid, crystalline compound which is set by the main composition of sodium chloride (over 8%) as well as other compounds such as Magnesium Chloride, Magnesium Sulfate, Calcium Chloride, etc. Salt has properties or characteristics that means it is easy to absorb water, bulk density (density) of 0.8 to 0.9 and a melting point at 801 ° C temperature level.

DEFINITION OF FUZZY

Fuzzy logic was first introduced by Prof. Lotfi A. Zadeh in 1965.Dasar fuzzy logic is fuzzy. On set theory of fuzzy set theory, the role of the degree of membership as a determinant of the presence of elements in a set is important. Value of membership or degree of membership or membership function became the main feature of the reasoning by the fuzzy logic (Kusumadewi, 2004).

Classical Association and the Association of Fuzzy

Basically, based on Kusumadewi et al (2013, pp. 9-43) that fuzzy set theory is an expansion of the classical set theory. In the decisive set (crisp), the value of membership of an item x in a set A is often written with $\mu_A[x]$, has two possibilities, namely:

- One (1), which means an item to be a member in a set, or
- Zero (0), which means an item not to be a member in a set.

Membership function (MF) is a curve that shows the mapping of points of input data into membership values that has interval between 0 and 1.

Linear Representation

In the linear representation, based on Kusumadewi et al (2013, pp. 9-43) that mapping input to the degree of membership can be described as a straight line.

a. Linear representation rose, which is the set began on domain values that have a degree of membership value zero (0) to move to the right toward the domain value having a higher degree of membership as shown in Figure 2.4. Membership functions:

$$\mu(x) = \begin{cases} 0 & ;x \leq a \\ \frac{(x-a)}{(b-a)} & ;a \leq x \leq b \\ 1 & ;x \geq b \end{cases} \quad (1)$$

b. Linear representation down, is the opposite of the first is a straight line that starts from the value of the domain with the highest degree of membership on the left side, then moves down to the value of a domain that has a lower degree of membership as shown in Figure 2.5. Membership functions:

$$\mu(x) = \begin{cases} \frac{(b-x)}{(b-a)} & ;\ a \le x < b \\ 0 & ;\ x \ge b \end{cases} \quad (2)$$

Fuzzy operator

As with a conventional set, there are some operations that are defined specifically for the combine and modify the fuzzy set. Based on Solikin (2011) that membership value as a result of operating two sets often known by name of fire strength or α-predicate. There are three basic operators created by Zadeh, namely: AND, OR, and NOT.

AND Operations

Based on Kusumadewi et al (2013, pp. 9-43) Operator relates to the operation of intersection on the set. α-predicate as a result of operations with the AND operator is obtained by taking the smallest membership value between elements on the sets concerned.

$$\mu_{A\cap B} = \min(\mu_A(x), \mu_B(y)) \quad (3)$$

Functions Implications

Based on Kusumadewi et al (2013, pp. 9-43) that each rule (proposition) in fuzzy knowledge base will be dealing with a fuzzy relation. The general form of propositions using fuzzy operator is:

If x is A then y is B

With x and y are scalar, and A and B are fuzzy sets. If the proposition that follows is referred to as antecedents, while the proposition that follows then called the consequent. This proposition can be expanded using fuzzy operator, such as:

IF $(x_1 is\ A_1)$• $(x_2\ is\ A_2)$• $(x_3\ is\ A_3)$• ….. •$(x_N\ is\ A_N)$ THEN $y\ is\ B$

with • are operators (eg OR or AND).

Composition Rules

From equation (4), based on Kusumadewi et al (2013, pp. 9-43) that if the system consists of several rules, the inference derived from the collection and correlation between rules. The method used in performing fuzzy inference system, the method Min (Minimum) on this method, a solution of fuzzy sets obtained by taking the minimum value of rules, and then use that value to modify the fuzzy region and applying it to the output using the AND operator. In general it can be written:

$$\mu_{sf}(x_i) = \max\left(\mu_{sf}(x_i), \mu_{kf}(x_i)\right) \quad (4)$$

with

$\mu_{sf}(x_i)$ = fuzzy membership value solutions to order to-i

$\mu_{kf}(x_i)$ = membership value of fuzzy rule consequent to-i

Model TSK fuzzy inference system

Based on Kusumadewi et al (2013, pp. 9-43) Fuzzy inference system method of Takagi-Sugeno-Kang (TSK) is a method for the fuzzy inference rules are represented in the form of IF - THEN, where output (consequent) system does not form fuzzy set, but in the form of a constant or linear equations. This method was introduced by Takagi-Sugeno-Kang in 1985. There are two models of the TSK methods, namely:

1. TSK method of order-0

   In general form of the model TSK fuzzy inference Methods Order-0:

   IF $(x_1 is A_1)$ ° $(x_2 is A_2)$ ° $(x_3 is A_3)$ ° ….° $(x_N is\ A_N)$ THEN $z = k$

with A_1 is the i-th fuzzy set as antaseden (reason), ° is the fuzzy operator (AND or OR) and k are constants firm as a consequent. In this method, antesiden represented by a proposition in fuzzy set, while the consequence is represented by a constant.

2. TSK-order method 1
   In general, the model fuzzy inference Methods Order TSK-1 are:
   $$\text{IF } (x_1 is A_1)^\circ \ldots .^\circ (x_N is \text{ A}_N) \text{ THEN } z = p_1 * x_1 + \ldots . + p_N * x_N + q$$
   the first is the i-th fuzzy set as antecedent, ° is the fuzzy operator (AND or OR), p_1 adalah constant of the i-th and q is also a constant in the Consequent.

   If the composition of the rules using the Sugeno defuzzification (dz) is done by finding the average value.
   $$z = \frac{\sum_{r=1}^{R} a_r z_r}{\sum_{r=1}^{r} a_r} \quad (5)$$
   with:
   a_r = is the value of output at the i-th rule
   z_r = is the degree of membership in the output value of the i-th rule
   R = is the number of rules that are used (Solikin, 2011).

RESULTS AND DISCUSSION

In this result discussed establishment of membership functions, establishment of fuzzy rules, and testing of the data and method. The salt we discussed is salt farmers which will be processed to be salt industries. From the data, maximum amount of salt is 20 kg and minimum is 5 kg.

Establishment of membership functions

The first process is to determine the membership function. From all the data, in getting some input membership functions and using equation (1) and (2), namely the function of wind speed, sun irradiation intensity, Rainfall and Production Total output membership function. For fuzzy sets and domain value to every variable can be seen in Table 1.

TABLE 1. Determining Domain Fuzzy Association

Name of Variable	Fuzzy Association Name	Domain
Wind Speed	LOW	[15 - 102]
	NORMAL	[58.5 – 145.5]
	HIGH	[102 - 189]
Intensity of the Sun Irradiation	LOW	[11 - 50]
	NORMAL	[30.5 – 69.5]
	HIGH	[50 - 89]
Rainfall	LOW	[-5 - 61]
	NORMAL	[28 - 94]
	HIGH	[61 - 127]

Establishment of Fuzzy Rules

After forming the membership function, the next step is to create fuzzy rules, because there are three input membership function fuzzy rules generated then there are 27 rules to include all of the variables. Fuzzy inference method used is the zero-order Sugeno. In this method, the antecedent is represented by propositions in fuzzy set, while the consequence is represented by a constant. To 27, the rule is:

[R1] IF wind speed is LOW and intensity of the sun irradiation is LOW and rainfall is LOW
THEN Average Total Production = 8.3083
[R2] IF Wind speed is LOW and Intensity of the sun irradiation is LOW and rainfall is NORMAL
THEN Average Total Production = 10.5083

[R3] IF Wind speed is LOW and Intensity of the sun irradiation is LOW and rainfall is HIGH
THEN Average Total Production = 12.7083
[R4] IF Wind speed is LOW and Intensity of the sun irradiation is NORMAL and rainfall is LOW
THEN Average Total Production = 9.9333
[R5] IF Wind speed is LOW and Intensity of the sun irradiation is NORMAL and rainfall is NORMAL
THEN Average Total Production = 12.1333
[R6] IF Wind speed is LOW and Intensity of the sun irradiation is NORMAL and rainfall is HIGH
THEN Average Total Production = 14.3333
[R7] IF Wind speed is LOW and Intensity of the sun irradiation is HIGH and rainfall is LOW
THEN Average Total Production = 11.5583
[R8] IF Wind speed is LOW and Intensity of the sun irradiation is HIGH and rainfall is NORMAL
THEN Average Total Production = 13.7583
[R9] IF Wind speed is LOW and Intensity of the sun irradiation is HIGH and rainfall is HIGH
THEN Average Total Production = 15.9583
[R10] IF Wind speed is NORMAL and Intensity of the sun irradiation is LOW and rainfall is LOW
THEN Average Total Production = 11.2083
[R11] IF Wind speed is NORMAL and Intensity of the sun irradiation is LOW and rainfall is NORMAL
THEN Average Total Production = 13.4083
[R12] IF Wind speed is NORMAL and Intensity of the sun irradiation is LOW and rainfall is HIGH
THEN Average Total Production = 15.6083
[R13] IF Wind speed is NORMAL and Intensity of the sun irradiation is NORMAL and rainfall is LOW
THEN Average Total Production = 12.8333
[R14] IF Wind speed is NORMAL and Intensity of the sun irradiation is NORMAL and rainfall is NORMAL
THEN Average Total Production = 15.0333
[R15] IF Wind speed is NORMAL and Intensity of the sun irradiation is NORMAL and rainfall is HIGH
THEN Average Total Production = 17.2333
[R16] IF Wind speed is NORMAL and Intensity of the sun irradiation is HIGH and rainfall is LOW
THEN Average Total Production = 14.4583
[R17] IF Wind speed is NORMAL and Intensity of the sun irradiation is HIGH and rainfall is NORMAL
THEN Average Total Production = 16.6583
[R18] IF Wind speed is NORMAL and Intensity of the sun irradiation is HIGH and rainfall is HIGH
THEN Average Total Production = 18.8583
[R19] IF Wind speed is HIGH and Intensity of the sun irradiation is LOW and rainfall is LOW
THEN Average Total Production = 14.1083
[R20] IF Wind speed is HIGH and Intensity of the sun irradiation is LOW and rainfall is NORMAL
THEN Average Total Production = 16.3083
[R21] IF Wind speed is HIGH and Intensity of the sun irradiation is LOW and rainfall is HIGH
THEN Average Total Production = 18.5083
[R22] IF Wind speed is HIGH and Intensity of the sun irradiation is NORMAL and rainfall is LOW
THEN Average Total Production = 15.7333
[R23] IF Wind speed is HIGH and Intensity of the sun irradiation is NORMAL and rainfall is NORMAL
THEN Average Total Production = 17.9333
[R24] IF Wind speed is HIGH and Intensity of the sun irradiation is NORMAL and rainfall is HIGH
THEN Average Total Production = 20.1333
[R25] IF Wind speed is HIGH and Intensity of the sun irradiation is HIGH and rainfall is LOW
THEN Average Total Production = 17.3583
[R26] IF Wind speed is HIGH and Intensity of the sun irradiation is HIGH and rainfall is NORMAL
THEN Average Total Production = 19.5583
[R27] IF Wind speed is HIGH and Intensity of the sun irradiation is HIGH and rainfall is HIGH
THEN Average Total Production = 21.7583

Testing

The first test was conducted on the No. 1 in which the data Input: 106.4 = wind speed, intensity of solar radiation = 64.9, rainfall = 1. Before inference should be sought beforehand degree of membership value of each variable in each set using equation (1) to (4).

Degree of membership of each variable on the input wind speed = 106.4

$$\mu_{LOW}[106.4] = 0, \quad \mu_{NORMAL}[106.4] = \frac{145.5 - 106.4}{43.5} = 0.89, \quad \mu_{HIGH}[106.4] = \frac{106.4 - 102}{43.5} = 0.10$$

Input : intensity of the sun irradiation = 64.9

$$\mu_{LOW}[66.3] = 0, \quad \mu_{NORMAL}[66.3] = \frac{69.5 - 64.9}{19.5} = 0.23, \quad \mu_{HIGH}[66.3] = \frac{64.9 - 50}{19.5} = 0.76$$

Input : rainfall = 1.

$$\mu_{LOW}[1] = \frac{1+5}{33} = 0.18, \quad \mu_{NORMAL}[1] = 0, \quad \mu_{HIGH}[1] = 0$$

Then searched the α-predicate (fire strength) of each fuzzy rule by using equation (2.5) and the operator and interpretation min, as follows:

[R1] IF Wind speed is LOW and Intensity of the sun irradiation is LOW and rainfall is LOW
THEN Average Total Production = 8.3083
α-predikat$_1$ = min (μ_{LOW} (106.4); μ_{LOW} (64.9);μ_{LOW} (1))
= min (0;0;0.18)
= 0
Z_1 = 8.3083

[R2] IF Wind speed is LOW and Intensity of the sun irradiation is LOW and rainfall is NORMAL
THEN Average Total Production = 10.5083
α-predikat$_2$ = min (μ_{LOW} (106.4); μ_{LOW} (64.9);μ_{NORMAL} (1))
= min (0;0;0)
= 0
Z_2 = 10.5083

To [R3] up to [R27] can be seen in the formation of fuzzy rules and do the same with [R1] to [R3] takes the value of the minimum so that the resulting α-predicate is not zero only in the rules [R13], [R16], [R22], [R25] then by using the weighted average method defuzzification in equation (5) then the average - average number of production are:

$$Z = \frac{\alpha_{13}z_{13} + \alpha_{16}z_{16} + \alpha_{22}z_{22} + \alpha_{25}z_{25}}{\alpha_{13} + \alpha_{16} + \alpha_{22} + \alpha_{25}}$$

$$Z = \frac{0.18*12.8333 + 0.18*14.4583 + 0.10*15.7333 + 0.10*17.3583}{0.18 + 0.18 + 0.10 + 0.10}$$

$$Z = \frac{8.221648}{0.56} = 14.681514.$$

To calculate the manual of all the data the same way with the first test and the test results with the results of the testing manual count calculation using the program matlab same result, of all the data values defuzzification can be seen in Table 2.

TABLE 2. Results defuzzification And Value Error

Week	Wind Speed	Intensity of the Sun Irradiation	Rainfall	Result Defuzzification	Data Result	Error
1	106.4	64.9	1	14.6825	8	6.6825
2	76.7	52.6	0.7	12.0913	5	7.0913
⋮	⋮	⋮	⋮	⋮	⋮	⋮
56	60.1	23.1	75.5	11.6829	5	6.6829

By using the Sugeno method can be produced Comparison of actual results with the results of defuzzification results in estimating the production of salt can be seen in Figure 1 which graph shows the actual data in blue and red color charts showing the results defuzzification.

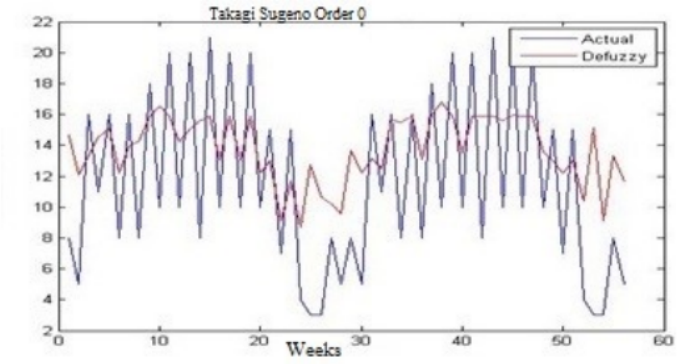

FIGURE 1. Takagi-Sugeno Fuzzy Graph Results for Order 0

Based on the results graph Sugeno fuzzy model obtained against predicted values yield different predictions with actual values. In addition to estimating the salt production error value obtained from the forecasts with actual results almost approaching accurately located in the weeks to five in 2014 and was in week fifth and week seventh in 2015 and the value of the error in the weeks that another very high. Therefore, the results of the error value is nearly accurate at out 2014 and 2015, from June to December there are only three weeks.

CONCLUSION

Based on the results of research and discussion, it can be concluded is of manual calculations and matlab using Sugeno zero-order error value of all the data used in this study were almost close to zero only in week seventh 2015 with result of the error value is 0.0917, for it can be said in estimating the salt production in week seventh by 2015 with wind speeds approaching normal height from 102 to 145.5 (km / h), intensity of solar radiation higher than 50 to 89 (mm) and low rainfall of -5 to 61 (h) the results of high-salt production.

For further development, it can be studied with adding four or more variables, so the calculation to estimate the amount of production is more accurate and we can compare this problem with another methods.

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