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OPTIMIZE TAKAGI SUGENO KANG FUZZY SYSTEM TYPE 1 COMBINATION STOCHASTIC GRADIENT DESCENT WITH ROUGH SET

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Abstract. Classification is a data analysis in which a model is being extracted in order to explain or differentiate the concept of each various classes of data. Fuzzy classification is one of the classification methods that is often being used because of its superiority non-flexible calculation so that it's possible to calculate uncertain possibility. In fuzzy method, there is a fuzzy set with the function to widen the range in characteristic function so that the function includes real number in [0,1] interval. One of recently well-known fuzzy method is Fuzzy Takagi Sugeno Kang (TSK). TSK method resulted in direct accurate output because of its rule where it use polynomial as consequences. In this research, the method used is fuzzy TSK with Rough Set which was optimized through Stocashatic Gradient Descent (SGD). The data used is secondary data obtained from database and being processed with Software Jupyter Notebook with Python as its programming language. The data is composed of cardiovascular data with 14 variables (13 input variables and 1 output variable). The model is evaluated by Root Mean Square Error (RMSE) and showed the average correspondence of the sum of squared prediction value and through observation of that data, resulting in 15,6. Based on the RMSE value obtained, it can be concluded that the used model is in a good category.

Keywords: Optimize, Fuzzy System Inference, Takagi Sugeno Kang, MBGD, SGD, Rough Set, RMSE

INTRODUCTION

Classification is a model which analyses and combines data and turn it into several different assigned classes [2]. The purpose of this is to find the right model that is able to predict the class of an object in every cases in data [3]. The crucial problem that lies in classification is how to determine which criteria that's needed to be classified [4].

Dimension reduction is used in attribute selection in dimension reduction of dataset with the consideration of irrelevant attribute, in which those attribute will distract the process and influence the accuracy in classification [5] . Reduct and Core then will be used in data containing big amount.

Rough Set Theory (RST) is a mathematical approach that is proven efficient in Knowledge Discovery in Database (KDD) which is used to solve inaccuracy, uncertainty, and risk [6]. The goal of this analysis is to obtain rule that is needed in classification after going through data collection, with classified rule as the result of reduct [7].

Membership function is primary characteristic when fuzzy logic is used [8]. Fuzzy logic is a branch of mathematic founded several years ago and has a daily concept that is heavily related with uncertainty [9]. Fuzzy has 3 components that is fuzzification, fuzzy inference, and defuzzification [10]. Fuzzy logic is easy to learn and does not have too many rules. It is also possible to get the desired output just in few steps [11].

Takagi Sugeno Kang fuzzy system (TSK) is often applied in classification problem and regression [12]. Additionally, it's widely used in health system, for the example its use to find for the solution of accurate diagnose from uncertainty problem in initial phase of disease. Generally, there are 3 strategies used to renew the parameter of TSK fuzzy system, which is Evolutionary Algorithm, Gradient Descent (GD) based algorithm, Gradient Descent (GD) and Least Square Information (LSE) [13].

Gradient descent is an optimizing algorithm where it uses partial derivative in each bias and burden [14]. Traditionally, it is obligatory to calculate the gradient from all of datasets to renew the parameter model iteratively, which takes a lot of time even forever in some cases with massive data size [15]. This research will use the algorithm of Stocashatic Gradient Descent (SGD) [16].

Algorithm of Stochastic Gradient Descent (SGD) is a simple approach that is efficient in discriminative learning to perform linier classification [17]. Stochastic Gradient Descent (SGD) is a variation from gradient descent algorithm which calculates the fault and repair the model for every dataset, in which every batch contains one observation that

is randomly chosen from a collection of training data so that the parameters are being modified once the gradient of each observation is done being calculated [18].

Cardiovascular disease is still the leading cause of mortality in Indonesia which resulted from unhealthy lifestyle. Heart is an organ with the function of pumping blood into every part of the body. It has such an important role in human so when its function is no longer good it may inhibit the other metabolism in the body [19].

Based on those explanation, this paper uses Rough Set, Takagi Sugeno Kang, and Stochastic Gradient Descent that is being applied in the data of cardiovascular disease.

METODH

Rough Set

The purpose of Rough Set is to determine the minimal amount of attribute reduction from table and remove excessive and irrelevant attribute from domain while abandoning the amount of loss in information.

In the process, there are some several steps needed that is Information system, Decision table, Indiscernibility relation (IND), and Reduct & Core.

The initial step, information system on data mining called dataset. Information system can be defined in the form of [20]:

$$S = \{U, A\} \tag{1}$$

In which $\boldsymbol{U = B_1, B_2, \dots, B_n}$ is filled finite group called universe. $\boldsymbol{A = x_1, x_2, \dots, x_n}$ is a finite group that is filled with elerly condition attribute.

Decision table is a special case from information system, it is defined by [21]:

$$S = \{U, A = C \cup \{D\}\} \tag{2}$$

Where D is not included in C dan $D = \{y\}$ is a satisfactory attribute.

Next, Indiscernibility is a variable selection that uses Rough Set, thus resulted in equivalent relationship that can be defined as [22]:

$$IDN_S(P) = \{(x, y) \in U^2 \mid \forall a \in P,\ a(x) = a(y)\} \tag{3}$$

where $a(x)$ show the attribute value a for x and $a(y)$ shows the attribute value of a for y

The last step, Core is a slice from all of the reduct. That makes the core to be included in every reduction, which translates to every core variable is included in several reduction [23].

$$Core(C) = Red(C) \tag{4}$$

where $Core(C)$ is an attribute group that is shared by reduction that is shared with all of C reduction and $RED(C)$ is a group of all C reduction.

Himpunan Fuzzy

If X is a group of object that states generally symbolized universe

with x is the member of the universe, so group of *fuzzy* A in X can be defined as:

$$A = \{(x, \mu_A(x)) | \, x \in X\} \quad (5)$$

Where $\mu_A(x)$ is called as membership function or membership degree of x in A which maps X into membership room in point [0,1] [24].

Fuzzy Takagi Sugeno Kang

The application of TSK fuzzy methode resulted in precise direct output, it is due to the fact that TSK fuzzy uses polynomial as the rule consequence. Down below is the steps of obtaining the output from TSK method:

First step fuzzification

Linear membership function up and down [25]:

$$\mu(x; m, n) = \begin{cases} 0 & x \le m \\ \frac{(x-m)}{(n-m)} & m \le x \le n \\ 1 & x \ge n \end{cases} \quad and \quad \mu(x; m, n) = \begin{cases} 1 & x \le m \\ \frac{(m-x)}{(n-m)} & m \le x \le n \\ 0 & x \ge n \end{cases} \quad (5)$$

Triangle linear membership function [25]:

$$\mu(x; a, b) = \begin{cases} \frac{(x-m)}{(m-n)} & n \le x \le m \\ \frac{(p-x)}{(p-m)} & m \le x \le p \\ 0 & others \end{cases} \quad (7)$$

Step 2, rule formation is assigining a rule in the shape of fuzzy implication that states the relationship between input variable and output variable with If-Then rule [26]. On this research, will be used Fuzzy Sugeno model orde one.

$$If\ (x_1\ is\ A_1).(x_2\ is\ A_2).\ldots.(x_n\ is\ A_n)\ Then\ z = p_1 * x_1 + \cdots + p_n * x_n + q \quad (8)$$

Where A_n is the n-th fuzzy group as antecedent, x_n is the n-th fuzzy group antecedent, p_n is the constant of n-th, . = fuzzy operator (AND or OR) $n = 1,2,3,\ldots,i$, and q = crisp constant as consequence.
Next, fuzzy inference is a process of taking a conclusion from correlation between rules and a group of fuzzy principle [27].

$$\mu F_1(x_i) \cup \mu F_2(x_i) = min\,[\mu F_1(x_i), \mu F_2(x_i)]\ \ untuk\ \ x_i \in \mathbb{R} \quad (8)$$

Where $\mu F_1(x_i)$ = membership value of fuzzy solution until the i rule and $\mu F_2(x_i)$ = membership value of fuzzy consequence with the rule of i with $i = 1,2,3,\ldots,n$
Last step, defuzzification value in Takagi Sugeno Kang can be found by calculating the centered average value [29].

$$z^* = \frac{\sum_{i=1}^{N} a_i z_i}{\sum_{i=1}^{N} a_i} \quad (11)$$

where a_i = output value in the rule of i, z_i = membership degree of output value in the rule of i, N = the amount of rule that is used with $i = 1,2,3,\ldots,n$

Stochastic Gradient Descent

Stochastic Gradient Descent (SGD) is a variant of gradient descent algorithm that calculates the error and renew the model in every dataset, where each batch has one observation $\boldsymbol{x^{(i)}}$ **and** $\boldsymbol{y^{(i)}}$. Stochastic Gradient Descent can be defined such as [28]**:**

$$W_k = W_{k-1} - \eta . \nabla_w j(W;\ x^{(i)}; y^{(i)}) \qquad (10)$$

where $\eta > 0$ is *learning rate (step size)*.
Root Mean Square Error (RMSE) is used a calculation tool to know the difference between the real data with prediction and the result is used as estimation model over observed value, that can be defined as:

$$RMSE = \sqrt{\frac{\sum(Y_i - \hat{Y}_i)^2}{n}} \qquad (12)$$

Where $\boldsymbol{Y_i}$ = real data, $\boldsymbol{\hat{Y}_i}$ =prediction value from $\boldsymbol{Y}$, $\boldsymbol{n}$ = the amount of observation

EXPERIMENTS AND RESULTS

On this research, there will be a classification using TSK type 1 with Rough Set which will be optimized with SGD, the data used are secondary obtained from Kaggle, a cardiovascular data with a total number of 303 data. The obtained variables are: sex ($\boldsymbol{X_1}$), age ($\boldsymbol{X_2}$), chest pain ($\boldsymbol{X_3}$), blood pressure ($\boldsymbol{X_4}$), cholesterol ($\boldsymbol{X_5}$), blood sugar ($\boldsymbol{X_6}$), electrocardiograph result ($\boldsymbol{X_7}$), heart rate ($\boldsymbol{X_8}$), exang ($\boldsymbol{X_9}$), oldpeak ($\boldsymbol{X_{10}}$), Ca ($\boldsymbol{X_{11}}$), thal ($\boldsymbol{X_{12}}$), slope ($\boldsymbol{X_{13}}$), dan target ($\boldsymbol{y}$). The group of data is showed in table 1.

Table 1: Cardiovascular Data Set

B_1	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	X_{10}	X_{11}	X_{12}	X_{13}	y
1	1	63	3	145	233	1	0	150	0	2.3	0	0	1	1
2	1	37	2	130	250	0	1	187	0	3.5	0	0	2	1
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮
303	0	57	1	130	236	0	0	174	0	0	1	1	2	0

From table 1 consisting of columns that represent attribute or data variable and rows that represent data object. Data from table 1 will use Rough Set method to determine which variables that has impact so that the results shown as following.

Table 2: Rough Set Result

B_1	X_2	X_4	X_5	y
1	63	145	233	1
2	37	130	250	1
⋮	⋮	⋮	⋮	⋮
303	57	130	236	0

According to table 2, the result of Rough Set that is X_1 = age, X_2 = blood pressure, X_3 = cholesterol, and y = target. The determination of the happening of cardiovascular disease, the data are shown in table 2.

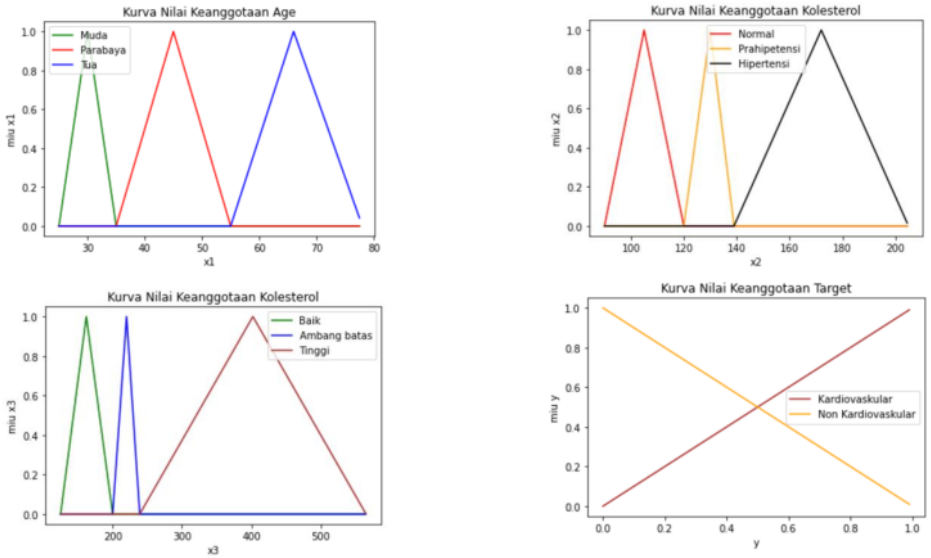
Table 3: Cardiovascular Disease Category

Age	Blood pressure	Cholesterol	Target
< 35 years old (Young)	< 120/80 mnHg Normal	≥ 240 High	< 450 (doesn't have cardiovascular disease)

35 - 55 years old (Middle-aged) > 55 tahun (Old)	120/80 - 139/89 mmHg Prehypertension > 140/90 mmHg Hypertension	200 – 239 Limit 200 High	> 450 (has cardiovascular)

The next step is to do TSK. According to table 2, it is obtained the result of Membership Function Fuzzy Logic in cardiovascular data as follows.

Figure 1: Result of Membership Function



After calculation of membership function, the rule is made and 25 rules are obtained which ten will be used in Takagi Suseno Kang with details as follow:

[R1] If X1 Elderly and X2 Prehypertension and X3 High so Y Cardiovascular
[R2] Jika X1 Middle-aged and X2 Prehypertension and X3 High so Y Non cardiovascular
[R3] Jika X1 Elderly dan X2 Hypertension dan X3 High so Y Cardiovascular
[R4] Jika X1 Middle-aged dan X2 Prehypertension and X3 Limit so Y Non cardiovascular
[R5] Jika X1 Elderly dan X2 Banyak dan X3 Light and X5 Thick so Y Non cardiovascular
... ...
[R25] Jika X1 Young and X2 Normal and X3 Limit so Y Non cardiovascular

According to the obtained rule, there is a need of optimization with SGD. The result of optimization is being presented in table 4.:

Table 4: Results of fuzzy with SGD

b_0	b_1	b_2	b_3
-0.633446	0.654497	0.968912	0.96902249
-0.728823	0.528409	0.595098	0.95712805
⋮	⋮	⋮	⋮
-0.345236	0.896429	1	0.97292264

DEFUZZIFICATION

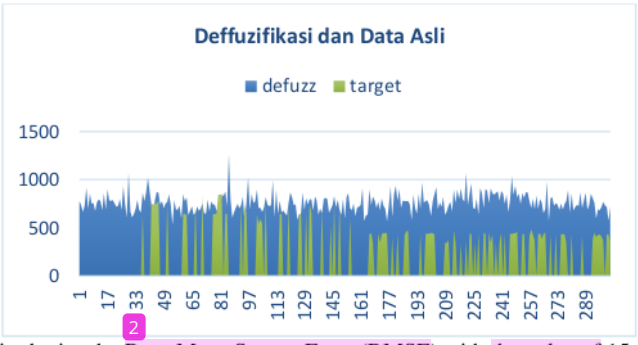
The result showed in table 4 then used to do defuzzification. The result of defuzzification is being compared to decision data in dataset.

Table 5: Results of defuzzification of actual data in cardiovascular

Defuzzification	Target (y)
145	700

130	756
⋮	⋮
130	344

Figure 2: Graph for the result of Defuzzification and real data in cardiovascular.



According to the picture, it obtains the Root Mean Square Error (RMSE) with the value of 15,61. The result explains that the model that is used qualifies in good category.

CONCLUSION

This paper uses Rough set, fuzzy Takagi Sugeno Kang (TSK) type 1, and Stochastic Gradient Descent (SGD) which is being applied in cardiovascular data. The output of fuzzy TSK is showed in the form of polynomial that is obtained from every rule. The result from RMSE method shows an error value of 15,61. Thus it can be concluded that the method used shows an outstanding result.

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