The Prevention Stroke for High-Risk Patients using Prediction and Treatment Based on Adaptive Neuro-Fuzzy Inference System (ANFIS)

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Abstract. Stroke is the second factor of mortality in the world. According to the World Health Organization (WHO), stroke is an acute brain dysfunction. The effects of stroke are disability and mortality. Therefore, this is a concern for world health. In early 2019, the Pandemic Covid-19 attacked the world and caused many mortalities. Especially, people who have complications with diseases such as heart attack, stroke, and asthma. The purpose of this research is to predict stroke diseases with input parameters (age, glucose level, heart rate, and BMI) and to test the accuracy of the system. Moreover, analysis of the management of stroke patients' strategy. ANFIS is a combination of ANN and FIS. It can construct a network realization of IF/THEN rules. This method was used by many researchers to predict and test the accuracy of the system. According to the result, the error of this system is 0.04 and the accuracy is 94%. Thus, it was good for predicting stroke diseases. According to the severity of the stroke, there are stroke management strategies that can be conducted by the patients; self-management and medical management. For self-management, problem-solving, goal setting, decision-making, and coping skills can help recovery. On the other way, there are five categories for medical management; stroke acute care, reperfusion, rehabilitation, cognitive decline, and neuroprotection and repair.
Keywords: Stroke, Hypertension, Prediction, ANFIS

2. Introduction

One of the diseases that causes the highest mortality is Stroke [1]. This disease can become a dysfunction of the nervous system that fails to transfer blood into the brain. World Health Organization (WHO) stated that stroke is an acute brain dysfunction [2]. The effects of stroke are disability and mortality. Therefore, this is a concern for world health. In early 2019, the Pandemic Covid-19 attacked the world and caused many mortalities. Especially, people who have complications with diseases such as heart attack, stroke, and asthma [3]. There are several indicators that influence patients to have a chance to get a stroke; such as gender, hypertension status, glucose status, stress, body mass index (BMI), and smoking status. According to the severity, Stroke is divided into two types which are hemorrhagic and ischemic [4]. According to that, it depends on the severity of the stroke which is permanent or temporary. Generally, ischemic stroke is a type of stroke that occurs when blood flow to the arteries in the brain is blocked [5]. Meanwhile, hemorrhagic stroke occurs in the brain and has leaked or ruptured blood vessels in the brain [6]. Thus, it is necessary to measure the aspects that can cause stroke such as glucose and heart rate, maintain body weight, avoid smoking and alcohol, and eat healthily.

For ischemic stroke, the patients need to consider nutrition to plan a diet food such as food that contains less salt, rich to consume of fruits, and vegetables, and avoids alcohol. [7] stated that meatless or vegetarian diets have significantly decreased the risk factors of stroke; hypertension, diabetes, and

hyperlipidemia. Nowadays, Artificial Intelligence (AI) has been played in the early phase to predict the diseases such as stroke, Covid-19, and immunity. One of the methods to predict the disease is using an Adaptive Neuro-Fuzzy Inference System (ANFIS). ANFIS is a method that combines between Takagi-Sugeno (Fuzzy Inference System) and Artificial Neural Network (ANN) [8]. ANFIS is human knowledge that uses fuzzy (if-then rules) that consist of input and output [9]. Many kinds of research were developed to predict this disease using ANFIS. [10] This research proposed to predict diseases of diabetes and cancer using ANFIS. This research used PIMA Indian diabetes dataset. ANFIS has proven to increase the accuracy of diabetes and cancer prediction. The aim of this study is to predict the possibility based on blood pressure, glucose level, and BMI. The results of this research are to prevent stroke in high-risk patients through prediction and treatment based on ANFIS. The treatment of stroke patients depends on the severity and impact on the brain. [11] stated that stroke management can be conducted in several steps such as assessment of the disease, prevention, and rehabilitation.

3. Methods

This research uses 53 data with four attributes; age, level of glucose, the pressure of blood, and body mass index (BMI). These attributes will be used to predict the patients who have certain criteria, it will be categorized by stroke or not. The data will be predicted using Matlab. The data has an age range of 14-81 years old. The lower and upper limit of blood pressure, BMI, and average glucose level is shown in Table 1. This data set will be conducted with training and testing.

Table 1. Lower and Upper Limit of Each Attribute

	Upper Limit	Lower Limit
Blood Pressure	90	210
BMI	23.7	54.6
Average Glucose Level	57.08	228.69

3.1. Stroke Disease

Stroke is the highest disease that affects mortality in the world. It can cause the disorder of nerve and cognitive. Some parts of stroke patients lack the transfer of blood, nutrient, and oxygen to the brain [12]. The historical disease supports the effects of stroke disease, especially hypertension. Hypertension may be reported as a cause of stroke because it can damage the brain cells that supply the blood [13]. Stroke can be divided into two types which are ischemic and hemorrhagic stroke. Ischemic stroke can be caused by lacking oxygen of blood supply to the brain. A hemorrhagic stroke generally can be caused by the rupture of an aneurysm in the brain parenchyma. Usually, stroke can be related to the patient who has several historical diseases, active smoking, high tension, obesity status, and high level of glucose [14].

3.2. Research Framework

The research framework is started to input the data. The stroke prediction data is according to the Kaggle data set. This research using 53 data set and the attributes are age, glucose level, blood pressure, and body mass index (BMI). The data will be trained and tested using ANN to measure the error and accuracy of the system. After that, construct the membership function using Sugeno-Fuzzy. The steps of fuzzy processing are the following in Figure 2. The research framework of the ANFIS to predict stroke diseases is shown in Figure 1.
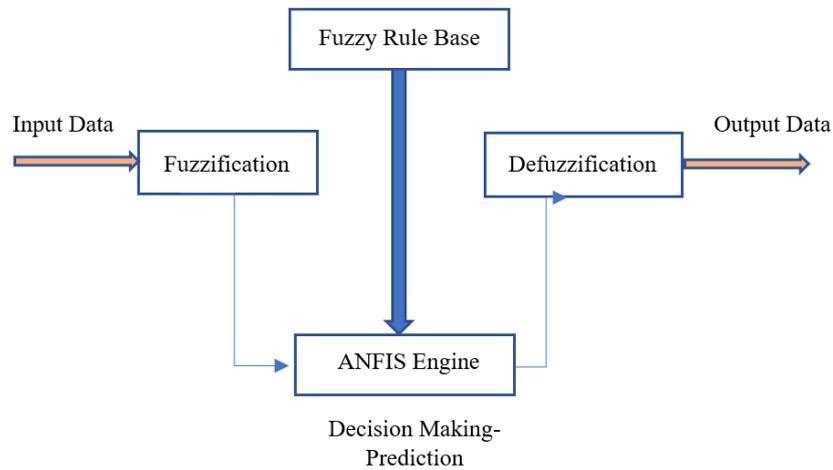
Figure 1. The ANFIS of Research Framework

3.3. ANFIS Architecture

Assumed that there are inputs (X and Y) and output (f). The rules are as follows [15]:

Rule 1:
IF X is A_1 and X_2 is C_1, then $Z_1 = p_1x_1 + q_1x_2 + s_1$

Rule 2:
IF Y is A_2 and X_2 is C_2, then $Z_2 = p_2x_1 + q_2x_2 + s_2$

Where
where pi, qi, and si (i = 1 or 2) are consequent parts of Sugeno fuzzy model. Figure 2 shows the ANFIS architecture for two inputs and one output.
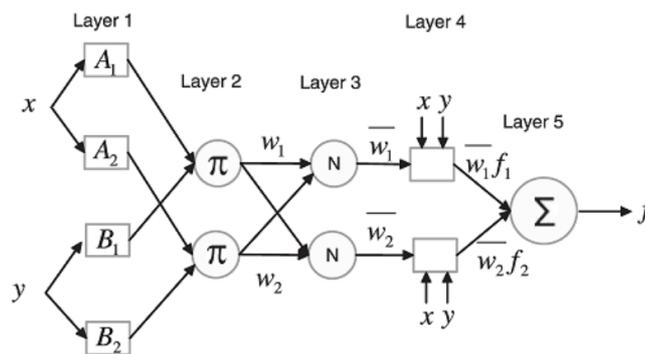

Figure 2. ANFIS Architecture with Two-Input Fuzzy [16]

As shown in Figure 2, There are five layers of ANFIS. the ANFIS architecture is according to the amount of input linked to the nodes.

Layer 1, for A_i and B_i, is the crisp to the node of fuzzy (low, medium, high). This is a linguistic label for the appropriate membership functions µAi and µBi. The rule used in this layer is AND rule that represents the antecedents for that rule.

$$O_{1,i} = \mu_A\ (x), \qquad\qquad \text{for } i = 1,2$$
$$O_{1,i} = \mu_{B\text{-}2}\ (y), \qquad\qquad \text{for } i = 3,4 \qquad\qquad (1)$$

Layer 2, it is a fixed node and the label is π. It indicates a simple multiplier. The symbol of w_i is represented by the output for this layer.

$$O_{2,i} = w_i = \mu_{Ai}\ (x_1)\ \mu_{Bi}\ (x_1), \quad \text{for } i = 1,24 \qquad\qquad (2)$$

Layer 3, it is called normalizing. The node in this layer is symbolized as N and as fixed node.

$$O_{3,i} = \overline{w}_i = \frac{Wi}{Wi + W2}, \qquad\qquad \text{for } i = 1,2 \qquad\qquad (3)$$

Layer 4, the name is the Defuzzying layer. All of the nodes in this layer (i) have the function to resulting the parameters (p_i, q_i, r_i), and w_i (i=1,2, etc) being normalized.

$$O_{4,i} = \overline{w_i y}_i = w_i\ (p_{ix} + q_{iy} + r_i), \quad \text{for } i = 1,2 \qquad\qquad (4)$$

Layer 5, The symbol of Σ is the total of output in ANFIS nodes.

$$O_{5,i} = y = \Sigma(\overline{w}_i y_i\ ), \qquad\qquad \text{for } i = 1,2 \qquad\qquad (5)$$

4. Result and Discussion
There are four input variables in this research; age (X1), the level of glucose (X2), pressure blood (X3), and weight body (BMI) (X4). Figure 5 shows the architecture of ANFIS. The first step of stroke prediction using ANFIS is to train the 53 data sets using ANN. The data will be trained until the error is close to 0. The data was stopped in 150 iterations with an error is 0.04. Figure 3 shows the data trained of the dataset.
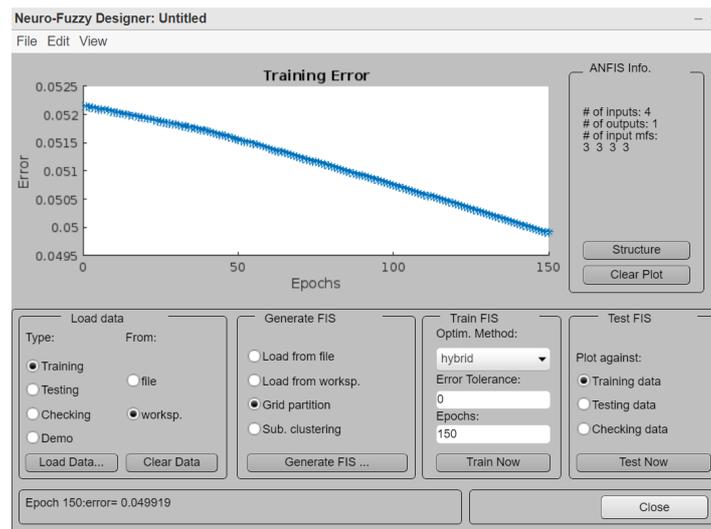

Figure 3. Training Error

Figure 4 shows that ANFIS architecture consists of five layers which are input mf, rules, normalization, output mf, and output. In the Fuzzy set, for the input membership function of each variable such as X1 (young, old, elderly), X2 (low, medium, high), X3 (low, medium, high), and X4 (low, medium, high). In this case, the rules obtained were 81 rules.

The example of fuzzy rules that combined as follows:

R1 : IF X_1 is young and X_2 is low and X_3 is low and X_4 is low THEN y is Out1
R2 : IF X_1 is young and X_2 is low and X_3 is low and X_4 is medium THEN y is Out2
R3 : IF X_1 is young and X_2 is low and X_3 is low and X_4 is high THEN y is Out3
R4 : IF X_1 is young and X_2 is low and X_3 is low and X_4 is low THEN y is Out4
R5 : IF X_1 is young and X_2 is low and X_3 is medium and X_4 is low THEN y is Out5
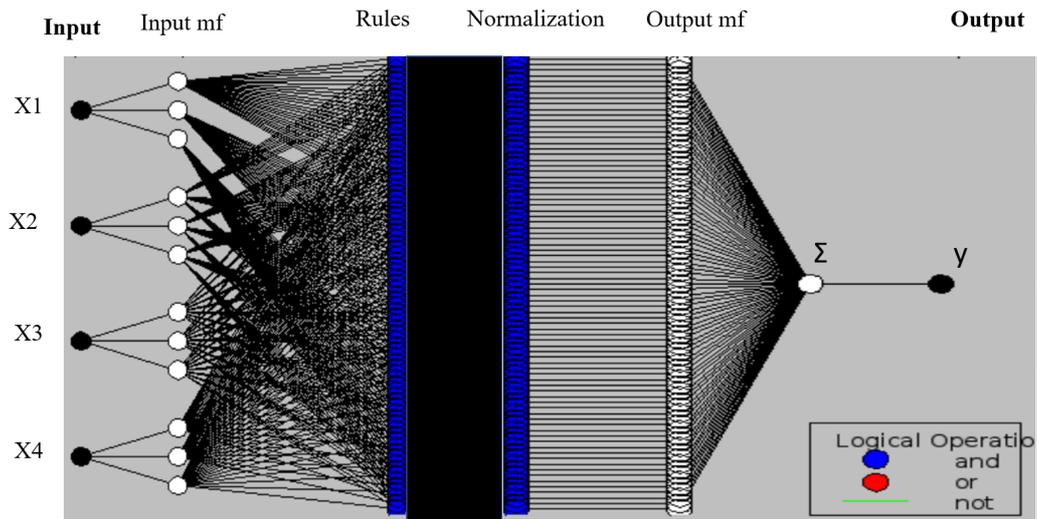

Figure 4. ANFIS Model Structure of Stroke Prediction

According to the final result, the accuracy of the system for predicting stroke disease is 96%, and the error is 4%. It means the system has high accuracy for prediction. According to the result, the range of glucose and blood pressure is 150-200 is categorized as stroke. It can be adjusted to another relationship for other attributes. The prediction of the relationship between glucose and blood pressure is shown in Figure 5.
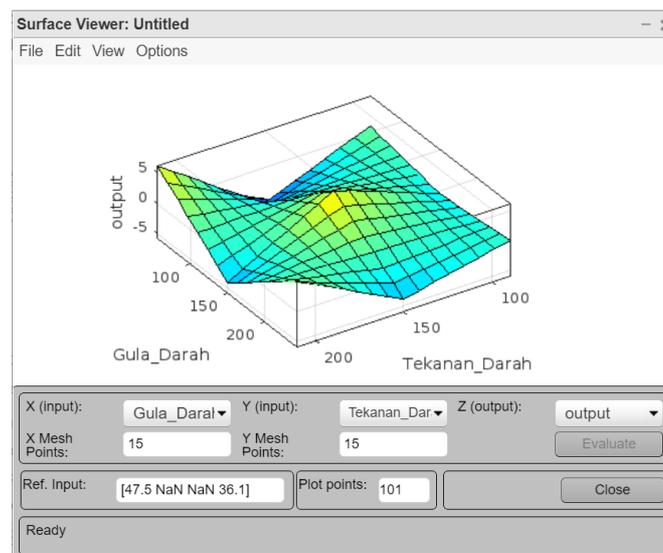

Figure 5. Stroke Prediction of Relationship Between Glucose and Blood Pressure

Many kinds of research explained parameters that influence strokes such as hypertension, diabetes, alcohol, smoking, and cholesterol [17]. Hypertension that well maintains can increase the risk of a

stroke. A blood pressure history of at least 160/100 mmHg is considered for stroke and 54% of people who are affected have these characteristics. Moreover, the smoker has a chance twice to suffer a stroke than rather non-smoker. Tobacco smoking contributes to 15% of mortality. In the individual aspect, the lack of a physical aspect can increase the risk of smoke and influence other diseases such as hypertension, diabetes, and obesity.
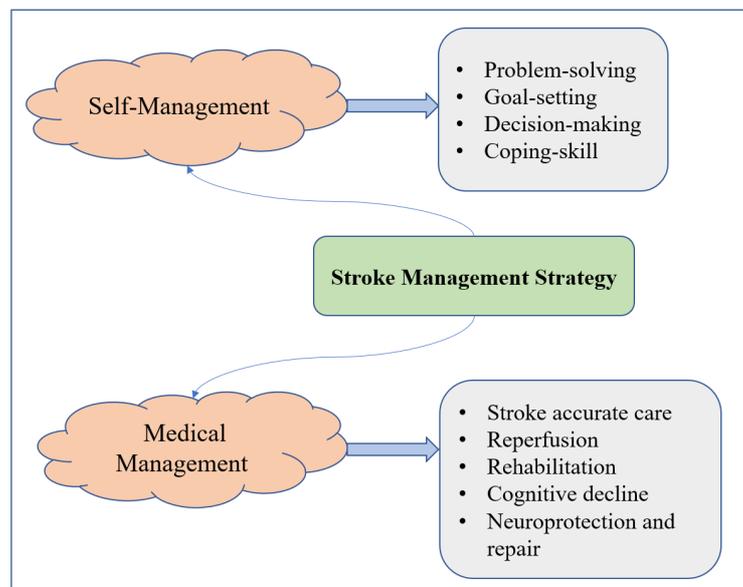

Figure 6. Stroke Management Strategy

There are some physical therapists that are used for the patients of stroke such as strengthening exercises, bed mobility, and sitting activities, transfer and gait training activities, facilitation of motor control, and use of equipment to exercise the strength of holding. The guideline for the treatment of patients after a stroke can be categorized into three; remediation, compensation, and motor control. Remediation means almost 20% of therapists use pre-functional activities such as strengthening the body parts. A compensation approach can be done by using a cane and walker for gait activity in order to encourage and help the patients to move from one place to another place. In motor control approach means that therapists must be spent more time with patients to do functional activities such as sit-to-stand, bed mobility, and transfer. According to a recent study, the management to treatment of stroke patients is called stroke management strategy. In some studies, stroke management can be conducted by self-management and medical management as shown in Figure 6. For self-management, the patients usually suffer a stroke in medium and low levels for severity. In recovery, the patients have to manage their self-in-skill training in order to encourage and take an active part [18].

[17] stated that the stroke management strategy has five categories; the first category is stroke acute care. This category is how to manage risk factors of stroke such as blood pressure, diabetes, alcohol and drugs, and hyperlipidemia. The second is reperfusion. In reperfusion, there are two treatments that can be conducted to help the stroke patient; Intravenous Thrombolytics (IVT), and Intra-arterial thrombolysis (IAT). IVT is a treatment using thrombolytic drugs, and IAT is a treatment using a catheter balloon. Bridging therapy is a combination of IVT and IAT for stroke patients. According to the study, bridging therapy can reduce the mortality rate by 17.9% in stroke patients [19]. The third category is rehabilitation. Stroke can cause the patient will lose short- and long-term memory. So, it needs to exercise such as walking, reading, and talking. Rehabilitation is conducted through physical therapy,

occupational therapy, speech therapy, and neurorehabilitation. The fourth category is cognitive decline. In these cases, there are decreasing capabilities of the brain, thus it needs to be helped with drug development, robotics, cortical stimulation, and stem cell therapy. The last category is neuroprotection and repair. It is important to avoid the risk factor of stroke in order to minimize the chance of affecting the stroke.

5. Conclusion

Many kinds of research conducted to predict stroke diseases. ANFIS can be used to train and test neural networks combined with fuzzy using rules. The nodes in the neural network are constructed according to four input attributes; age, glucose level, blood pressure, and body mass index (BMI). According to the result, ANFIS can be trained and tested for the error of the system until 0.04. It means the system has 94% of accuracy which is a good prediction. In physical therapy for stroke patients, it can be some approaches such as remediation, compensation, and motor control. In stroke management strategy, there are two ways to help recover the patients; self-management and medical management. For self-management, there are several ways to encourage skill training; problem-solving, goal setting, decision-making, and coping skills. On the other way, self-medical there are five categories; stroke acute care, reperfusion, rehabilitation, cognitive decline, and neuroprotection and repair. The limitation of this research is the attributes of the data. For future research, it will use medical records, such as CT scan results and historical diseases. Thus, it can increase the precision of system prediction.

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