Analysis of membership function in implementation of adaptive neuro fuzzy inference system (ANFIS) method for inflation prediction

M A Raharja1, I D M B A Darmawan2, D P E Nilakusumawati3 and I W Supriana4

124Informatics Department, Faculty of Mathematics and Natural Sciences, Universitas Udayana, Jl. Raya Kampus Unud Jimbaran, Kec. Kuta Sel., Kabupaten Badung, Bali 80361, Indonesia
3Mathematics Department, Faculty of Mathematics and Natural Sciences, Universitas Udayana, Jl. Raya Kampus Unud Jimbaran, Kec. Kuta Sel. Kabupaten Badung, Bali 80361, Indonesia

*made.agung@unud.ac.id

Abstract. This research will analyze which fuzzy membership function (MF) gives the best results in the implementation of the Adaptive Neuro-fuzzy inference system (ANFIS) method. The case study conducted is to predict the growth of inflation in Bali Province with ANFIS which has the main objective of analyzing the fuzzy membership function and designing a model that can predict the value of inflation growth. Inflation can also be defined as a process of increasing general prices or decreasing the value of money continuously. Inflation growth prediction uses the ANFIS method with five input parameters in the form of regional economic indicators, and the number of pairs of initial data used is 34 annual periods. Several types of membership functions (MF) that will be tested and analyzed are triangular MF, MF trapezium, and MF gbell. The cryptic inference system used is TSK-Order One, and the learning method used is a hybrid method. Based on the research results, the analysis of the fuzzy membership function in the inflation prediction system produces the best error is 1.35E-07 with the type of triangular membership function (MF).

1. Introduction
Forecasting is the act of making predictions on future situations. In many areas of life, forecasting is a basic technique for targeted decision making to minimize risks in decision making and reduce unexpected costs [1], [2]. Regional economic recovery must be supported by an active role between the people and the government which can produce a better economic condition. This is also supported by the existence of statistical data information that is useful to assist in planning a policy, namely as a consideration in future decision making. Government policies can be taken appropriately if they are based on accurate and timely statistical information. One of the indicators used as a measuring tool to describe the level of development success in terms of the economy is the level of inflation. Inflation can be interpreted as an increase in the price of goods in general and continuously [3]. An increase in one or two goods cannot be called inflation, unless it causes a large increase in the price of the other goods. Inflation is the most important issue which reported at the end of the year as a local economic indicator. One of the benefits of prediction is for the problem of economic statistics, namely regarding the prediction of future inflation values. Inflation can be defined as a general and continuous...
increase in the price of goods. Focusing on price changes issue is reasonable since this variable indicates not only economic stability but also affects social welfare in the country [4]. Economic growth gives information about how well the economy performed [5].

This research will combine the ability of artificial neural networks and fuzzy systems to predict time series data or what is often referred to as hybrid. Using the fuzzy logic system, you will find difficulties in determining the rules that will be included in the basic rules of the fuzzy system and the difficulties encountered in designing how many layers in a neural network can be overcome by combining these two systems into a neuro-fuzzy system ANFIS structure (Adaptive Neuro - Fuzzy Inference System) [6]. Soft computing methods represent an approximate solutions for precisely formulated problems.

To determine the type of membership function based on the properties of the membership function, several types of membership functions (MF) will be tried, namely: MF triangular, MF trapezium, and MF gbell [7]. ANFIS (Adaptive Neuro-Fuzzy Inference System) can provide solutions for predictive system models that are able to adapt well to handle complex, nonlinear and time-changing systems through learning algorithms against system numerical data.

2. Method
In this study using a system development method with an early stage Input in this system for the training and checking process is in the form of data on inflation growth indicators from 1985 to 2019, totaling 34 data. The data is then divided into two parts, namely 19 data for training and 15 data for checking. Data on inflation indicators, especially in Bali, consists of 4 influencing indicators.

2.1. Adaptive Neuro Fuzzy Inference System (ANFIS)
A neural network is a network structure in which the overall input-output behavior is determined by a modified set of parameters [8]. One of the neural network structures is multilayer perceptrons (MLP). This type of network is specifically the feed-forward type. MLP has been applied successfully to solve difficult and varied problems by training it using error backpropagation (EBP) algorithms [2].

Furthermore, the fuzzy system can describe a system with linguistic knowledge that is easy to understand. Fuzzy inference systems can be trained with back propagation algorithms based on input-output data pairs using a neural network architecture. This way allows cryptic systems to learn. This combination of cryptic systems with neural networks is called neuro-fuzzy.

2.2. ANFIS structure
The neuro-fuzzy system with ANFIS (Adaptive Neuro Fuzzy Inference System) structure or commonly known as Adaptive Network-based Fuzzy Inference System is included in the neural network class but based on its function is the same as fuzzy inference system. In neuro-fuzzy, the learning process on a neural network with a number of data pairs is useful for updating cryptic inference system parameters [9].

Figure 1a illustrates the consideration mechanism for Sugeno’s model; ANFIS structure for the same function is shown in Figure 1b, where the vertices in the same layer have the same function. The output of each node in screen 1 is written O1, i [4].
2.3. Determining the type of membership function

Based on the properties of the membership function, several types of membership functions (MF) will be tried, namely: triangular MF, MF trapezium, and MF gbell [11]. In the training process that will be explained later, each component of Government Consumption, Investment, Export, Inflation and Foreign Tourist Visits will be divided into several cryptic groups, namely as many as 3. For the division of components of Low, Medium, and High government consumption into 3 cryptic groups, the form of its membership function along with its linguistic value is more or less like Figure 2.

The membership function for each cryptic set is formulated as follows.

**Low Set:**
\[
\mu_{\text{Low}}(x) = \begin{cases} 
1; & x \leq -16 \\
-6 - x/10; & -16 \leq x \leq -6 \\
0; & x \geq -6 
\end{cases}
\]

**Medium Set:**
\[
\mu_{\text{Medium}}(x) = \begin{cases} 
0; & x \leq -6 \\
x + 16/10; & -6 \leq x \leq -6 \\
1; & -6 \leq x \leq 8 \\
18 - x/10; & 8 \leq x \leq 18 \\
0; & x \geq 18
\end{cases}
\]

**High Set:**
\[
\mu_{\text{High}}(x) = \begin{cases} 
0; & x \leq 8 \\
x - 8/10; & 8 \leq x \leq 18 \\
1; & x \geq 8
\end{cases}
\]

2.4. ANFIS architecture

The first stage, as many as 34 data on Government Consumption, Investment, Net Exports, Investment and Tourist Arrivals, from 1985 to 2019, will be input data to the system. These data will be used as input for the data training process at ANFIS. Then, as much as 31 inflation data is used as output.
In this ANFIS architecture, the basic rules to be used are as follows. Only three rules are shown, the 243 rules are as follows:

\[
\begin{align*}
\text{Layer 1} & \quad \text{Layer 2} & \quad \text{Layer 3} & \quad \text{Layer 4} & \quad \text{Layer 5} \\
X_1 & \quad W_1 & \quad W_2 & \quad W_3 & \quad W_4 & \quad W_5 \\
X_2 & \quad W_6 & \quad W_7 & \quad W_8 & \quad W_9 & \quad W_{10} \\
X_3 & \quad W_{11} & \quad W_{12} & \quad W_{13} & \quad W_{14} & \quad W_{15} \\
X_4 & \quad W_{16} & \quad W_{17} & \quad W_{18} & \quad W_{19} & \quad W_{20} \\
X_5 & \quad W_{21} & \quad W_{22} & \quad W_{23} & \quad W_{24} & \quad W_{25} \\
\end{align*}
\]

**Figure 3.** ANFIS architecture with 5 (five) input parameters and 5 (five) layer

Figure 3 shows 5 (five) parallel correlated layers where each layer can be described as follows: In the second layer, the inference engine process is carried out (fuzzy inference system) and determines fuzzy rules for the next calculation process. In this process, the Takagi Sugeno model is used. In this study, 234 rules were used.

The third layer is to calculate the ratio of the rule of the ith degree of membership to the sum of the rules of the degree of membership, so that the value is obtained. In the fourth layer, the defuzzification process is carried out by calculating transforming the cryptic results into a crisp output form. The fifth layer is a single node which computes the output by adding up all the input signals.

### 3. Result and Discussion

This section describes the results of testing the Adaptive Neuro Fuzzy Inference System (ANFIS) method used in the Inflation prediction system that was designed and implemented in the previous chapter. Tests are carried out to see the quality of the prediction system performance by assessing the reliability and accuracy of each combination of training parameters.

In the first part, it explains about testing the combination of parameters that will be used in the training process, namely training data and data checking as well as the number of epochs, the number of fuzzy membership, and error tolerance to get the suitable MF type based on the best RMSE value.

#### 3.1. System Description

The ANFIS Modeling System that will be built functions to produce a Fuzzy inference system using the Sugeno-order 1 order cryptic model ANFIS method by utilizing the input output data pair to conduct training on the cryptic inference system that will be generated. Input and output data needed for training are data on economic indicators related to inflation.
3.2. System Testing
Tests are carried out on the combination of parameters that will be used in the training process, namely training data and data checking as well as the number of epochs, the number of fuzzy membership functions, and error tolerance.

For more details, the results of the third ANFIS training can be seen in Table 1.

| No. | Data | Type MF | MF   | Epoch | Error Tolerance | Error Training |
|-----|------|---------|------|-------|-----------------|----------------|
| 1   | 19   | gbellmf | 3    | 1000  | 1.00E-07        | 5.65E-07       |
| 2   |      | trimf   |      |       | 1.66E-07        |                |
| 3   |      | trapmf  | 3    | 1000  | 1.00E-07        | 1.35E-07       |
| 4   |      | gbellmf | 1    |       | 4.41E-07        |                |
| 5   |      | trimf   | 1    |       | 1.35E-07        |                |
| 6   |      | trapmf  | 1    |       | 3.44E-07        |                |

From the results of testing Table 1 using the parameters mentioned in the previous section, it is found that the best RMSE training data is obtained from parameters, namely: total data = 15, MF type is trimf with RMSE value = 1.35E-07. For more details, it can be seen in Figure 4 for a total of 16 training data.

![Graph of ANFIS training results with a maximum epochs of 1000](image)

(a) Generalized bell mf type, (b) Triangular mf type and (c) Trapezoid mf type.

**Figure 4.** Graph of ANFIS training results with a maximum epochs of 1000
Based on Figure 4, it can be seen that the ANFIS training process comparison chart using a combination of test parameters. The maximum number of epoch 1000 and the three different types of cryptic membership sets, the results of the anfis training process are only the Gbell membership function type which has not shown a convergent graph.

4. Conclusion
Inflation growth prediction simulation using ANFIS with a hybrid learning algorithm, yields the best error is 1.35E-07 with the type of triangular membership function (MF) using 15 pairs of testing data. The type of function and the amount of data will affect the final fuzzy inference system obtained which affects the predictive analysis, as evidenced by the variation in the RMSE value of the total test results.

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References
[1] Uko S S, Simeon O, and Daniel I J 2019 Adaptive Neuro-Fuzzy Inference System (ANFIS) Model for Forecasting and Predicting Industrial Electricity Consumption in Nigeria
[2] Ghore S, and Goswami A 2015 Short Term Load Forecasting of Chhattisgarh Grid Using Adaptive Neuro Fuzzy Inference System International Journal of Science and Research 4 11
[3] Aparicio D, and Bertolotto M I 2020 Forecasting inflation with online prices International Journal of Forecasting 36 2:232-247
[4] Sriyana J 2018 Determinants of Inflation in the Local Economy Etikonomi Jurnal Ekonomi 17 1:1-10
[5] Alamsyah A, and Permana M F 2018 Artificial neural network for predicting indonesian economic growth using macroeconomics indicators 2018 International Symposium on Advanced Intelligent Informatics
[6] Jovic S, Miladinovic J S, Micic R, Markovic S, and Rakic G 2019 Analysing of exchange rate and gross domestic product (GDP) by adaptive neuro fuzzy inference system (ANFIS) Physica A: Statistical Mechanics and its Applications 513: 333-338
[7] Takagi T, and Sugeno M 1985 Fuzzy identification of systems and its applications to modeling and control IEEE transactions on systems, man, and cybernetics 1:116-132
[8] Wang Y, Wang L, Chang Q, and Yang C 2020 Effects of direct input–output connections on multilayer perceptron neural networks for time series prediction Soft Computing 24 7:4729-4738
[9] Abbas S A 2017 A comparative study of artificial neural networks and adaptive Neuro-fuzzy inference system for forecasting daily discharge of a Tigris river International Journal of Applied Engineering Research 12 9 2006-2016
[10] Adedeji P A, Akinlabi S, Madushele N, and Olatunji OO 2020 Hybrid adaptive neuro-fuzzy inference system (ANFIS) for a multi-campus university energy consumption forecast International Journal of Ambient Energy:1-10
[11] Long H V, Jebreen H B, and Chalco-Cano Y 2020 A New Continuous-Discrete Fuzzy Model and Its Application in Finance Mathematics 8 10:1808