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Tsunami Potential Prediction with Artificial Neural Network

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ABSTRACT

Natural disasters are caused by biological factors such as earthquakes, tsunamis, and landslides. One of the destructive natural disasters that can cause considerable losses in terms of casualties and the economy is the tsunami. A tsunami is a series of tall or long waves in shallow seas. Various tsunami triggers include earthquakes, volcanic activity, and underwater landslides. This study aims to predict tsunamis with an Artificial Neural Network, which is a part of Machine Learning. Artificial Neural Network (ANN) is a model that has the same characteristics as biological neural networks. The process resembles the work of a neural network, which processes incoming information through neurons—using Multi-Layer Perceptron with five input parameters, two hidden layers, and one output. The ANN model can predict a tsunami potential in a country by 81%.

Keywords: Tsunamigenic, Earthquakes, Machine Learning, ANN

I. INTRODUCTION

Based on the definition of disaster according to Indonesian Law Number 24 of 2007, a disaster is an event or series of events that threatens and awaits people's lives and livelihoods caused, both by natural factors and non-natural factors as well as human factors resulting in human casualties, damage environment, property loss, and psychological impact. Natural disasters are defined as disasters caused by an event or series of events caused by nature, including earthquakes, tsunamis, volcanic eruptions, floods, droughts, hurricanes, and landslides.

Tsunami comes from the Japanese ("tsu" which means ocean, and "nami" which means wave), so a tsunami is a series of high sea waves that arise as a result of a shift in the seabed due to an earthquake. According to Sutopo, the potential for a tsunami disaster in Indonesia ranks first out of 265 countries worldwide. This risk even surpasses Japan, with 5,402,239 people potentially affected. Tsunamis occur due to several factors, namely, volcanic activity, earthquakes, and landslides. Most of the tsunamis that occur in the world are caused by earthquakes.

Machine Learning (ML) is a method that creates programs that can learn from data, learn patterns, then can determine the results. One branch of ML is deep learning. Deep learning uses Neural Networks to solve problems. Neural Networks are derived from "neurons" or nerves. Artificial Neural Network (ANN) is a mathematical model with a working nervous system. The characteristics are: (1) Has a pattern of connections between neurons, (2) Method for determining the weight of the connection, (3) Activation function [1]. This model can be applied in determining weather forecasting [2], predicting the magnitude of earthquakes [3], identifying tsunamigenic earthquakes with seismic waves [4], and real-time forecasting of tsunami waves at close range in coastal areas using machine learning [5] which has a high degree of accuracy. Based on this, modeling will be carried out to determine the potential tsunami risk in an area with ANN and predict tsunami height with ANN.

II. METHODS

A. Tsunami

A tsunami is a wave or a series of shallow water waves that usually occur in the ocean. Tsunami triggers include earthquakes, submarine gravitational masses, volcanic activity, landslides, and cosmic impacts or atmospheric disturbances. At first, it was referred to as "oshio," which comes from Japanese and means high tide, then the term Tsunami was introduced, which means "tsu" is a wave and "nami" is a harbor. Tsunamis are destructive waves, especially on the coast. Several tsunami incidents were dangerous and caused considerable losses in terms of loss of life and property, namely the events that occurred in Aceh, Indonesia (2004) and Tohoku, Japan (2011).

After the two major tsunami events occurred, research on tsunami disasters has increased in the last decade, especially since the incident in Aceh (2004). Some of the developing research topics include numerical modeling and tsunami generation, propagation and inundation of tsunamis, field surveys in search of sedimentary traces and offshore geomorphology from pre-/historical tsunami impacts, tsunamigenic effects of earthquakes and gravitational masses, as well as observations of tsunami waves in the ocean. And along the coast using DART (Deep-ocean Assessment and Reporting of Tsunamis), satellites, and other instruments [6]. Furthermore, various kinds of tsunami models and forecasting have been developed. One way is to use machine learning, namely Artificial Neural Networks.

B. Artificial Neural Network (ANN)

Artificial Neural Network (ANN) is a model that has the same characteristics as biological neural networks. The process resembles the work of a neural network, which processes incoming information through neurons. Signals pass between neurons through a link, where each related link has an associated weight that multiplies the transmitted signal. Furthermore, each neuron has an activation function to obtain the output. ANN can be trained to perform specific tasks by adjusting the weight values between these elements [7].

a. Multi-Layer Perceptrons

Multi-Layer Perceptron (MLP) is a feedforward network consisting of three layers: input, hidden, and output. Information from the web is given to the input layer and production. The node from the input will then receive the data and pass it on to the hidden layer (neuron). The neuron model and architecture of the neural network will then determine how the input is converted into output. These transformations involve calculations and can be represented by detailed mathematical algorithms. The perceptron then calculates a single production from several inputs, forming a linear combination according to the input weights and then obtaining an output through the sigmoid activation function in this study. The network weights can then be adapted using a gradient-based optimization algorithm. The computational process is then repeated until the consequences have converged.

b. Activation Function

The activation function is a function that is added at the end, functioning as a determinant of whether the neuron should be active or not based on the total weight of the input. In general, there are two activation functions, linear and nonlinear. By default, the activation function is linear; the neuron's output is the sum of the weights and the input plus the bias.

Nonlinear activation functions include tanh, sigmoid, and ReLU functions.

Tanh Function

The tanh function is defined as follows:

$$f(x) = \tanh x$$

This function has a value range between -1 to 1, used for data classification or data groups.

Sigmoid Function

The sigmoid function is defined as follows:

$$f(x) = 1/(1 + e^{-x}).$$

This function has a range of values between 0 and 1. Like the tanh function, it is widely used in data classification or data groups.

ReLu Function

The ReLu function is defined as follows:

$$R(z) = \max(0, z)$$

Furthermore, an illustration of each activation function can be seen in Figure 1.

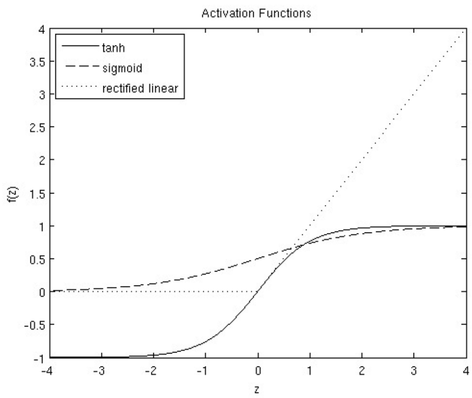

Figure 1: Activation Function

This study uses a quantitative and systematic approach. The research carried out is to determine the model, predict the potential for a tsunami originating from an earthquake, and model and predict the height of a tsunami in Indonesia.

The data used in this study is secondary data sourced from https://catalog.data.gov, which is the World Significant Earthquake Database, and there are 5,700 earthquakes. The variables used in the research based on these data sources are the earthquake that caused the tsunami, Focal Depth (Earthquake Depth), earthquake magnitude, MMI maximum intensity, and the location of the earthquake (latitude and longitude). The data used is then processed using Python.

Determining the Neural Network model in research, there are eight stages which can be seen in Figure 3[8]. The stages in Figure 3 are then explained in the following steps:

Stage 1. Data Collection

Data is collected from various sources based on the required variables.

Stage 2. Data Processing

Furthermore, data processing is carried out, one of which is by doing data cleansing.

Stage 3. Data Selection

The input and target (output) variables are determined at this stage.

Stage 4. Subset Data Selection

The data is divided into training data and testing. Usually, it is 70% data training, 30% data testing, 80% training, and 20% training. The selection depends on the researcher and the data used.

Stage 5. Model Training

The data that has been divided is then trained using the ANN model.

Stage 6. Model Selection

Next, an optimized ANN model is performed

Stage 7. Model Validation and Sensitivity Analysis

The next stage is the model is validated by seeing how accurate the model is

Stage 8. Final Model

The most accurate model is then determined as the best model.

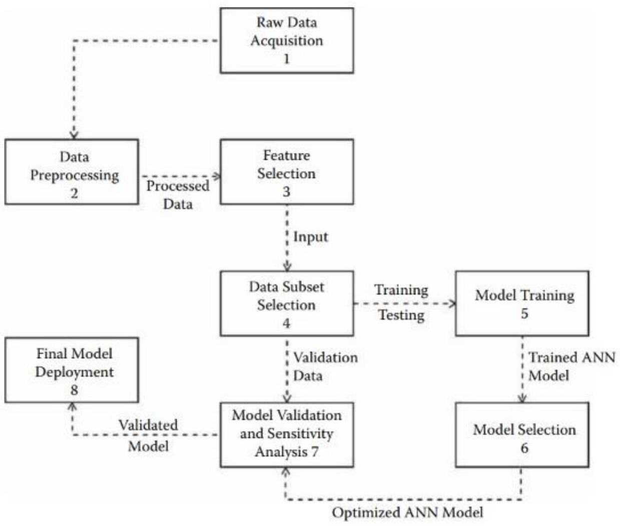

Figure 2: Model Stages

III. RESULTS AND DISCUSSION

A Tsunamigenic is an event in nature that has the potential to cause a tsunami. This incident is in the form of disturbance of seawater by volcanic activities, earthquakes, coastal and underwater landslides, and other causes [9]. In this study, the focus is on tsunamigenic events that occur due to earthquakes. The earthquake was a sizeable destructive earthquake with a magnitude of more than 5. The following is a map of the distribution of countries that experienced tsunamis.

The World Significant Earthquake Database used in this study has several variables. However, not all variables are used in this modeling process. The variables used in this study are Focal Depth, earthquake magnitude, MMI maximum intensity, and earthquake location (latitude and longitude) to predict the potential for a tsunami. The first step that must be done is to look at the data structure of the variables that have been determined previously. The following is a descriptive statistic of the data used in this study.

Figure 3: World tsunami distribution map

TABLE 1
DESCRIPTIVE STATISTICS FROM THE WORLD SIGNIFICANT EARTHQUAKES DATABASE

	Earthquake Depth (km)	Earthquake magnitude	MMI maximum intensity	Latitude	Longitude
Total	1220	1220	1220	1220	1220
Mean	34.12	6.58	7.58	21.88	28.06
Standard Deviation	50.71	1.03	1.9	25.03	92.819
Q1	0	3.2	2	-53.5	-177.88
Q2	22	6.6	8	34.18	32.28
Q3	35	7.5	9	40.61	115.02
Maximum	664	9.5	12	64	179.14

Based on Table 1. The average depth of the earthquake that caused a tsunami was under 100 km,

Figure 5: Tsunamigenic Artificial Neural Network Architecture

34.12 km, with an average earthquake magnitude of 6.58, which was more than 5. And the maximum intensity of the MMI was 7.78.

The second step is to examine the proportion of the target variable discussed in this study. The target variable in this research is the tsunami potential of a country. This target variable contains two types of tsunami potential; the first 0 interprets the situation of a tsunami occurring in that country, while 1 interprets the case of not having a tsunami in that country. The proportion of potential tsunamis from the data used in this study can be seen in Figure 4.

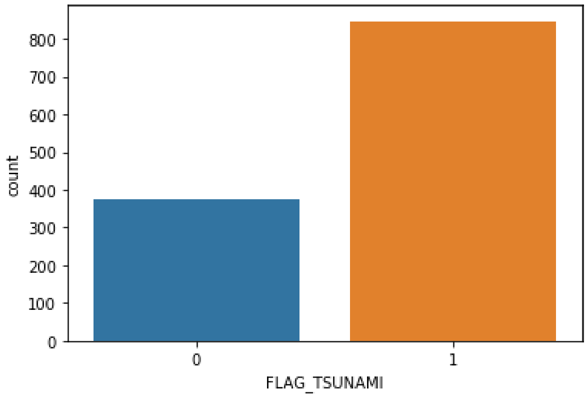

Figure 4: Tsunami Potential Proportion

It can be seen in Figure 4 that the proportion of the target variable needs to be balanced. Therefore, the next step is to resample to ensure these proportions are balanced. Then, the data will be divided into two parts, namely training and test data, with a ratio of 80 to 20. The data that has been separated will be used to model using an Artificial Neural Network, as shown in Figure 5. In Figure 5, the ANN architecture of the tsunamigenic data used is by five input parameters with the first ten hidden layers, the second 6 hidden layers, and one output, namely Yes/No Tsunami occurrence.

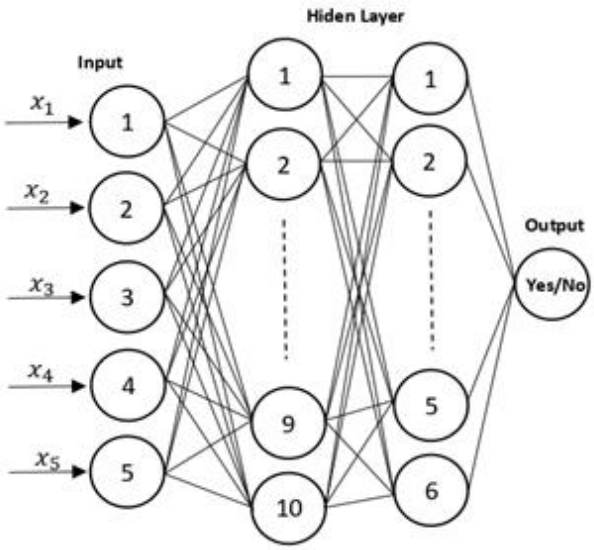

Figure 5: Tsunamigenic Artificial Neural Network Architecture

The next step is to model the training data using an Artificial Neural Network. As explained in the previous section, the Artificial Neural Network model is a model that connects layers to produce an output using activation. Therefore, the first thing to do is determine the layers of the ANN model. This data uses three layers; the first layer has ten hidden units, while the second layer has six hidden units. The activation function used to connect the layers in this study is the Relu activation function. The last layer consists of one output unit with a sigmoid activation function. The following results of training data modeling using ANN with different batch-size variations.

From the results of training data modeling with batch size variations, it was found that the best accuracy was obtained from variations with batch sizes of 5 and 100, resulting in an accuracy of 77.45%. Modeling the training data using ANN is optimized using the Adam optimizer. Furthermore, steps can be taken to validate the model from the ANN by using test data. Then the accuracy of the data obtained is 81%. This means that the ANN model can predict a tsunami potential in a country by 81%.

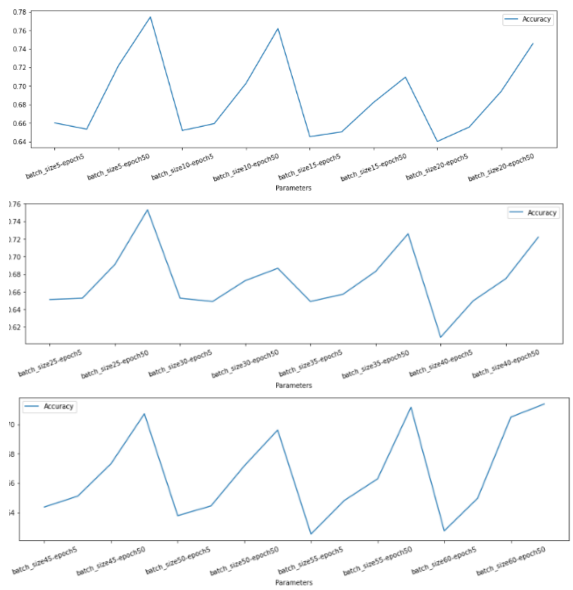

Figure 6: ANN model accuracy on Data Training

IV. CONCLUSION

Based on the results and discussion, it can be concluded that ANN can predict the potential for a tsunami. The ANN architecture on the tsunamigenic data uses five input parameters, two hidden layers, and one output. The activation function used in each layer uses the Relu activation function, while the output activation function uses the sigmoid activation function. This ANN model can predict a tsunami potential in a country by 81%.

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