Comparison between Fast EP-ANN and Classical EP-ANN for Lightning Prediction

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Abstract – **One of the methods for lightning prediction is by using an Artificial Neural Network (ANN) prediction system for lightning occurrence based on historical lightning and meteorological data from Malaysian Environment. Using this method has a few problems about to finding suitable network architectures. This paper presents the improvement of method ANN with Evolutionary Programming (EP) as an optimization technique. This optimization technique will optimize to find ANN architectures systematically with less computation time. The mutations operators in EP discuss in this paper are Fast-EP which apply Cauchy mutation and Classical-EP which apply Gaussian mutation and the comparison for both of its. The best value sets of input data taken whether by using a Cauchy or Gaussian mutations and both operators will be compare to decide which the most suitable operators for lightning prediction is. As the result, the most suitable technique will create the best ANN architectures.**

Keywords-lightning prediction, artificial neural network, Fast-EP, Classical-EP, Cauchy mutation, Gaussian mutation, optimizing technique.

I. INTRODUCTION

Lightning is an electrical discharge and one of the power full energy which that brings high energy at millions of volts and a few tens kilo ampere current. It also produces high temperature of about 30,000°C within a few tens of milliseconds. That is why lightning is very dangerous for people and can cause fire and damage to any electrical equipment either directly and indirectly [1]. Malaysia ranks as one of the highest lightning activities take place. This is because by referring to worldwide isokeraunic levels, the average thunder day in Kuala Lumpur is within 180 to 300 days per year [2]. That is important for Malaysia to understand meteorological system and the data have been recorded by the Malaysian Meteorological Services (MMS) and a private utility company, the Tenaga Nasional Berhad (TNB) [3, 4]. Concerns about the dangerous of lightning effect, many methods have been developed in order to predict lightning occurrence. One of the methods is by using artificial neural network (ANN) [2].

Artificial Neural Network (ANN) is a method by using mathematical method or computational method that can be described as an intelligent machine learning technique based on the operation of biological neural network [5, 6]. ANN is the most popular method for the various engineering and non-engineering applications. For example of the applications are prediction, pattern recognition, system identification, and classification and control system. ANN is made up of interconnecting element of artificial neurons and processes information that operate in parallel [3]. These elements are inspired by biological nervous system. This method is very suitable for prediction because ANN have the ability to learn by example or data and do the task based on training experience [4]. ANN also can be trained to perform a particular function and can adjust itself when input and output data presented relative to a specific functional relationship so that it can give a good representation of that relationship even when the relationship is not linear and not well defined because this method have the ability to handle complex non-linear functions [3,4]. However, ANN technique still has the problem to design the best ANN architecture because it is only use the try and error method. To overcome this problem, optimization technique is performed to get the best ANN architecture and can predict lightning occurrence with less computational time [3, 5].

Evolutionary programming (EP) is a population-based generate-and-test approach, in which mutations are the only search operators to generate new solutions [7]. This is one method to optimize the problem of ANN architecture. There are many mutation operator provides in EP but this paper only discuss on the Fast-EP which apply Cauchy mutation and Classical-EP which apply Gaussian mutation and the comparison for both of its [7]. The best values set of input data taken whether using Cauchy and Gaussian. The EP is implemented to optimize the value of learning rate and momentum constant to improve the system to be more accurate in prediction lightning [3]. Mutations operators will be generate offspring and the best offspring will be creating the best of learning rate and momentum constant for ANN architecture. In this paper, ANN with EP optimization technique is presented as the platform for lightning

prediction system based on historical and meteorological and to become the best of the lightning prediction technique [3].

II. METHODOLOGY

The fundamental components of ANN lightning prediction system is by using the historical lightning and meteorological data because its provide the necessary information for ANN. The purpose of the data is to learn about the event that happened in the past. The data includes the input and output data for training purpose. The data were taken from Subang (3°7' N, 101°33' E or latitude: 3.13, longitude: 101.53), Selangor provided by Malaysia Meteorological Services (MMS) and Tenaga Nasional Berhad (TNB) [3]. The data used was from the hourly data and the parameters which pressure, dew point temperature, surface wind, rain fall, cloud height, dry bulb and moisture difference were chosen as to play the important role in shaping the occurrence of lightning [6]. All the data will be used in order to perform training and testing phase in ANN. Besides that, the methodology in this paper also presents the configuration of ANN architecture, selection of ANN configuration, training and testing process, improving generalization as well as the optimization process using EP technique [3].

A. Design of ANN system

Matlab software is used to design the architecture ANN. ANN is divided into two process which call as training process and testing process. In designing ANN, three layers feed forward network with back propagation rule are design by using Matlab software [3, 5]. The first layer is an input layer that consists of input data that use for training and testing process. The second layer is a hidden layer which connected from input layer to receive the information and produce the output and that will become the input for a third layer or final layer. The final layers is called output layer that will be produce the desired result. Meteorological data will be use as input for input layer and the lightning occurrence is asserted as the output of ANN.

In ANN architecture, each layer designed has its own number of neurons. There can be any number of neurons and the best of neurons need to obtain the best output data of lightning occurrence by using heuristically [3]. Transfer function is one of basic buildings block that use in designing ANN. This transfer function is responsible in producing the output for each neuron until it reach the final layer and produce desired output. This transfer function also determined by using heuristically [3, 5]. At the hidden layer is the main of the process for ANN to produce the output of lightning occurrence. Evolutionary programming is being applied at this layer to optimize the value of learning rate and momentum constant to improve the system performance with less computation time. Figure 1 below shows the process of ANN lightning prediction system with the improvement using the optimization technique.

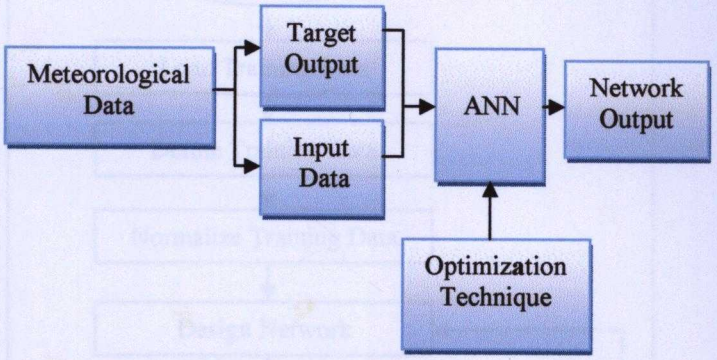

Figure 1: ANN system with optimization technique

B. Selection of ANN parameter

The best ANN architecture depends on the best network configuration. The network configuration such as number of neuron and the types of transfer function determined by varying those configuration to get the value of regression coefficient, R close to 1. This varying technique that is call it's a heuristically to get the learning rate and momentum constant and will be fixed at typical value when find the best parameter. Besides that, the number of neurons was not set too large to avoid the computational complexity of the network. This will be cause the high of time taken for convergence and minimize the error. The transfer function of the network is also important and each of the transfer function has been tested in the network to obtain the best of ANN architecture.

C. Training process

In order to determine the best design, ANN need to be trained before it's perform any prediction so that it's learns to become more experience and familiar with the pattern of the data inserted. The training process uses the levenberg-Marquardt algorithm, ***trainlm*** which is usually used in supervised learning [3]. Historical and meteorological data will be set as the input and output which the input, p for meteorological about the weather data and the target, t for data lightning occurrence. The data is preprocessed using their min and max values giving the data in range of [-1, 1]. This is because the data is normalized so that they always fall within a specified range. After training, the result will be to the next step that's call as testing process. The network will be produce output with zero mean and unity standard deviation and the network is trained until it achieve a very small error, reach the maximum number of epoch, performance goal met or stop by the stopping condition [3, 4].

D. Improving generalization

ANN has the ability to generalize that is important for a prediction lightning [5]. Improving the generalization avoid the problems of over fitting due to unstable generalization. The over fitting occurs when the error of the training set is small, but when a new set of data is loaded to the network, the error become large. The regularization method is present in order to improve the generalization. The method will stop the training automatically even though the training process has not met the minimum error as set in the program. The method itself is able to perform early detection of over fitting occurrence. This method involves the modifying of the performance function which refers to the sum of squares of the network errors on the training phase. Without this improvement method, the training process will continue until it meets the minimum error [3].

E. Testing process

The purpose of testing process is required to check and measure the performance of the trained network. This process involved testing the trained network with new sets of inputs and target data. Same as the training process [3]. The data has been normalized by using their min and max so that they fall within the range of -1 to 1. Then the output will be convert to original form by performing the post-processing step (de-normalize). In order to determine the best of the system, a linear regression method has been performed. This method is compares between network outputs and targets and at the same time computes the correlation coefficients (R) to check the quality of the network. A network with r close to 1 is the best network architecture where the outputs produced and the target is approximately same. The whole processes are presented in the form of a flow chart as in Figure 2.

F. Optimization process

The optimization process by EP techniques can use either two mutation operators which call as Cauchy mutations in Fast-EP (FEP) or Gaussian mutations in Classical-EP (CEP). The technique optimizes the parameter value in ANN whether uses Gaussian mutation or Cauchy mutation as the primary search operator. The parameter needs to be optimize are learning rate and momentum constant. The result is which of both operators will create the best parameter whether Gaussian mutation or Cauchy mutation. There are several steps implemented in completing the process of optimization technique as follows:

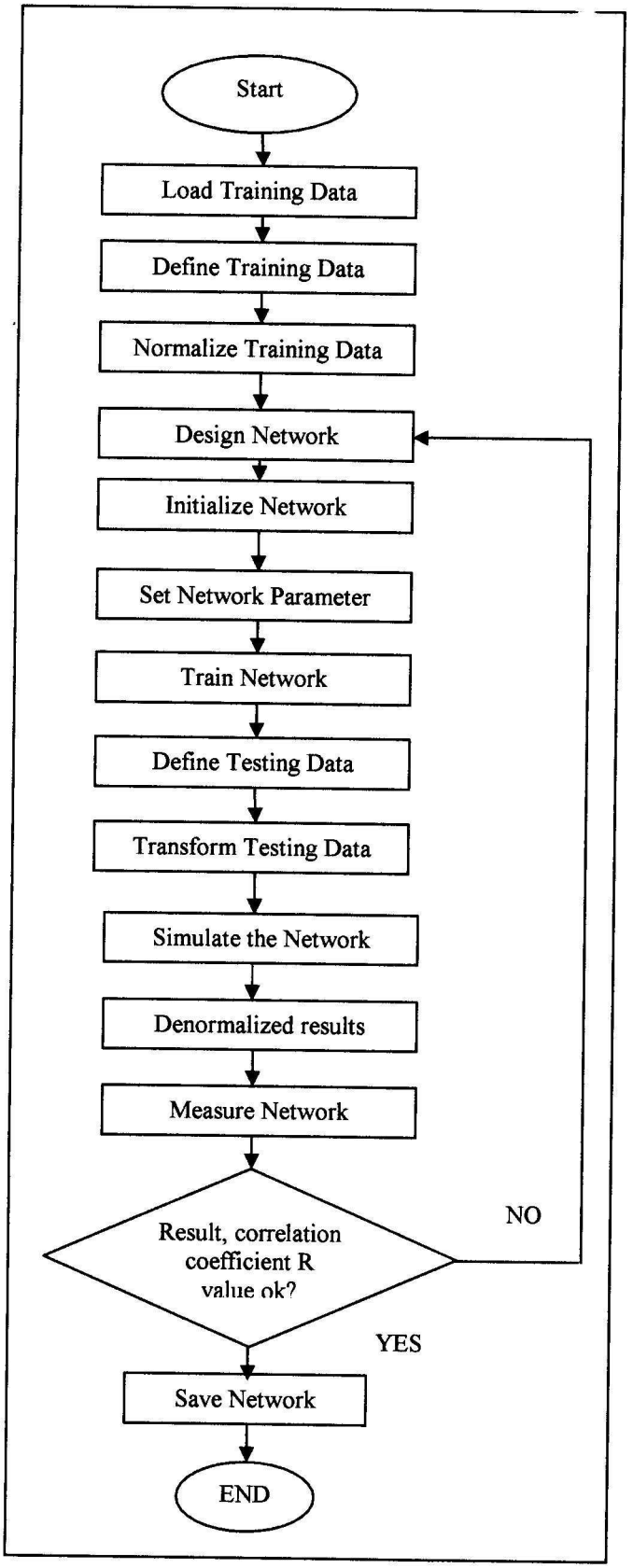

Figure 2: ANN Flowchart

Step 1: Initialize population
The first step in EP is to generate 5 initial parents denoted by x1 and x2 randomly to become the learning rate and momentum constant respectively which also known as objective variables. Each of the pairs has their own strategic parameter as the standard deviation for the Gaussian mutation denoted by n1 and n2. Both the variable and parameter were set into range 0 to 1 [3].

Step 2: Calculate fitness 1
Calculate fitness for each individual of objectives variables referring to the objective function.

Step 3: Mutation process
A new population is created and set as the offspring or children to the parents generated before by using equation (1) and (2). The creation of a new population implement by first user is Gaussian mutation and second user is Cauchy mutation as an operator δj. The values of offspring's generated were set to fall in a range of 0 to 1 which is the same as in the step 1 process.

$$xi'(j) = xi(j) + ni(j)\delta j, \quad \ldots (1)$$
$$ni'(j) = ni(j)\exp(\tau' N(0,1) + \tau Nj(0,1)) \quad \ldots (2)$$

Step 4: Calculate fitness 2
This process calculates the fitness of each offspring's generating in the mutation process before. The process will be using the same objective function in calculate fitness 1.

Step 5: Combination
Combine the parents and offspring's that give the number of population becomes 10 set.

Step 6: Selection
This is process of selection to get the best 5 populations. The process will select the population based on the correlation coefficient R with arrangement of maximum to minimum R value. The winner of the selection will be the new parents of the next generation.

Step 7: Convergence test
This test is conducted to stop the process of optimization. It will stop if the stopping criterion is satisfied. The difference between maximum and minimum of R value will determine the stopping criterion which is get to 0.01. The optimization process will keep on repeating from mutation process onwards until it satisfied the condition of stopping criterion. All the steps taken are shown in Figure 3.

III. RESULT AND DISCUSSION

The performance of the network seen to perform better when the training data set to 88% while the testing data used is 12%. The configuration indicates that a network go through training process with more training data will be trained well.

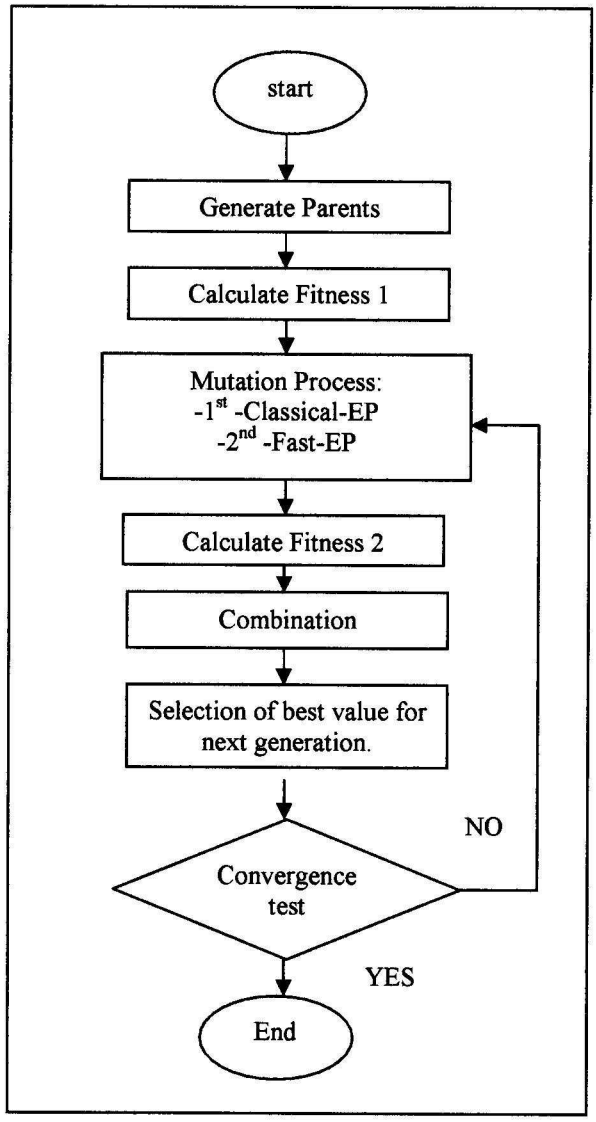

Figure 3: Evolutionary Programming Flowchart

It is also observed that the best ANN architecture with *[8, 5, 1]* number of neurons and *logsig, logsig, purelin* transfer function shows the best performance. Other than that, the method of regularization has improved the performance of the network and decrease the time of training with its ability to prevent over fitting. The Multi-operator EP was used in ANN system to define the best parameter of learning rate and momentum constant. By using the Gaussian mutation in EP, the learning rate 0.3050 and momentum constant 0.9568 is the best values obtained which produced R value of 0.9571. The total time taken was 1590.40 second. For Cauchy mutation, the learning rate and momentum constant obtained is 0.2617 and 0.4927 respectively. The computation time to define the parameters recorded is

1273.10 and the value of R is 0.9896. This is prove that by using Cauchy mutation in Fast-EP, the result obtained give the value of R which approaches to 1 and time taken to define the parameters faster than using the Gaussian mutation in Classical-EP. Table 1 show the comparison result and Table 2 provided the best ANN architecture by using the Cauchy mutation.

Table1: Comparison between by using Fast-EP and Classical-EP

EP Technique	LR	MC	Times(s)	R Value
Fast-EP	0.2617	0.4927	1273.10s	0.9896
Classical-EP	0.3050	0.9568	1590.40	0.9571

Table 2: Properties of ANN architecture for lightning prediction system by using Fast-EP.

ANN Properties	Properties
No. of input variables	5
Training pattern	150
Testing pattern	20
Network configuration	*[8, 5, 1]*
Transfer functions	*logsig, logsig, purelin*
Learning rate	0.2617
Momentum constant	0.4927
Time	1273.10s
Training function	Trainlm
Generalization improvement method	Regularization
Regression coefficient, R	0.9896

IV. CONCLUSIONS

This paper presents ANN with EP to define the best parameters whether using Cauchy mutation in Fast-EP or Gaussian mutation in Classical-EP. It is designed for lightning prediction based on the historical and meteorological data to become the input and target data. The best result is achieved by done the comparison that shows using Cauchy mutation is better than Gaussian mutation. These operators take the best learning rate and momentum constant as a parameter of ANN system. By using Cauchy mutation, the value of R is more approaches to 1 and the time taken is faster to trainee and testing data than Gaussian mutation. As a result, the developed lightning prediction system is able to obtain by using Cauchy mutation operator in Fast EP and prediction of the lightning occurrence can be successfully done.

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