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STUDY OF LINE SEARCH TECHNIQUES ON THE MODIFIED BACKPROPAGATION FOR FORECASTING OF WEATHER DATA IN INDONESIA

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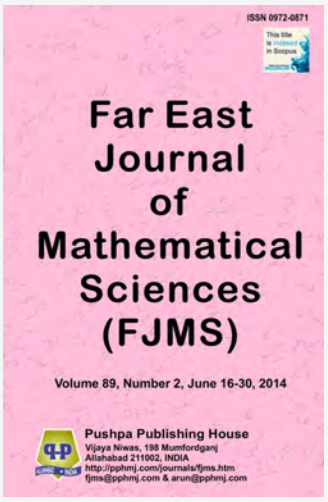

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STUDY OF LINE SEARCH TECHNIQUES ON THE MODIFIED BACKPROPAGATION FOR FORECASTING OF WEATHER DATA IN INDONESIA

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Abstract

The extreme alteration of weather condition in Indonesia at the last two decades is the main idea that encourages this research. Recently, we have been built an improvement system of backpropagation performance by using conjugate gradient on forecasting of air temperature and humidity in Indonesia [1]. Data of weather used in this research is derived from Indonesian Agency for Meteorology Climatology and Geophysics covering air temperature, rainfall, air humidity, length of sun radiation, air pressure, and wind velocity in Kemayoran Jakarta area along five years (2007-2012). In this paper, we examine a technique of line search on conjugate gradient for backpropagation training in the forecasting of temperature, humidity, and air pressure. The technique of line search plays a part in determining step size parameter on conjugate gradient to minimize

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the process of searching. Eventually, the proposed method provides good performance, in addition to the training needs of small epoch compared to the standard backpropagation.

1. Introduction

The Straits Times notices that Jakarta has a significant flood once every five years. The last big one was in 2007, killing around 50 people and displacing over 200,000 residents. While the National Disaster Mitigation Agency notices that heavy rain over the Jakarta at January 2013 caused 32 deaths and at its peak forced nearly 46,000 people to flee their inundated homes. The phenomenon of weather alteration is felt extreme enough in several last years, and it needs anticipations from all parties. Previously, we have already built a system of forecasting air temperature and humidity by using modified backpropagation [1]. Backpropagation can solve several cases such as recognizing pattern, forecasting, classifying and so on. But then, standard backpropagation algorithm has several obstacles, one of them is length of training. It will happen when selecting the parameters is not suitable with that training, for instance, selecting learning rate that affects to weight changes [2, 3]. Those some obstacles have been overcome with adaptive method of learning rate, but they have not achieved convergence yet in the fast time [4, 6].

In this time, Artificial Neural Network (ANN) is a study of algorithm that is often used on solving cases of forecasting. It is caused by ANN that be able to recognize the existing patterns, therefore, it can predict well. One of learning methods from ANN is backpropagation where this method can produce satisfied result in prediction. Even so, it still has a weakness, namely the training process needs a long time, even if the parameters used are not suitable. This weakness can be solved by Conjugate Gradient (CG) algorithm to accelerate the training of backpropagation [5]. There are several types of conjugate gradient, namely Polak Ribiere, Fletcher Reeves, and Powell Beale [7]. In this paper, the conjugate gradient algorithm is implemented to optimize learning rate of backpropagation training as modified backpropagation training algorithm is expected to obtain better system

performance. In this paper, we examine the role of line search techniques on the conjugate gradient algorithms in backpropagation training for forecasting of weather data.

2. Data and Method

Some factors that influence the phase of weather data are: previous rainfall, temperature, humidity, air pressure, length of radiation and wind. In a result, with the six elements data that form weather and climate, a system can forecast the air temperature, humidity and pressure. Data of weather which is used in this research is obtained from Indonesian Agency for Meteorology Climatology and Geophysics (BMKG). The data used in this research is derived from BMKG gained by using the tools of Automatic Weather Station (AWS). These data are daily and include air temperature (°C), humidity (%), length of sun radiation (lpm), air pressure (millibar), rainfall (millimeter), and wind velocity (knots) in Kemayoran area (Jakarta) along five years (2007-2012).

Conjugate gradient is one of optimization methods which the direction of searching is based on conjugate direction whose value is orthogonal. Because the direction of search is orthogonal, the conjugate gradient gets up to convergence quickly to the solution sought. Conjugate gradient can be used not only to solve a linear function, but can also be used for nonlinear problems, such as engineering design, training of artificial neural networks, and nonlinear regression. There are several types of conjugate gradient method, such as Polak Ribiere, Fletcher Reeves, and Powell Beale [8]. In this paper, the conjugate gradient algorithm is implemented to optimize learning rate on backpropagation training. Conjugate gradient algorithm as modified backpropagation training algorithm is expected to obtain better system performance.

Method of Conjugate Gradient (CG) is a searching algorithm with a direction of searching is always not stable. In other words, it depends on the direction of its conjugation. Thus, generally this algorithm is faster on convergence than standard backpropagation. Here, conjugate gradient uses

non-zero vectors which orthogonal and linear independent. The two vectors are called *orthogonal* (*G-conjugate*) if its inner product equal to zero. Hence, we should optimize weight which is link among neurons in order to minimize errors that happen.

Conjugate gradient is a method to minimize subordinate function by using approach w_{k+1} based on:

$$w_{k+1} = w_k + \alpha_k d_k, \tag{1}$$

$$d_{k+1} = -g_{k+1} + \beta_k d_k, \tag{2}$$

where α and β are momentum parameters (to avoid local convergence) [7, 9].

To update weight uses the following formula [1]:

$$w_{j+1} = w_j + \alpha_{j+1} d_{j+1}, \tag{3}$$

where

w_{j+1} : weight will be updated

w_j : previous weight

α_{j+1} : current Alfa value

d_{j+1} : direction of current iteration.

Parameter α is determined by using technique of line search to minimize searching process. Some techniques of line search are:

1. *Golden Section Search*, namely searching simple linearity without calculating gradient from the line.
2. *Brent's Search*, namely searching linearity by using combination between golden section search and quadrate interpolation.
3. *Hybrid Bisection-Cubic Search*, namely searching linearity by using combination between bisection method and cubic interpolation.
4. *Charalambous' Search*, namely searching method that constitutes a combination between cubic interpolations and sectioning type.

3. Design Forecasting System

Training process is built in the server, while learning process will be done in the server. Then optimum parameter from learning result is used on the process of forecasting that is done on the android based gadget like at Figure 1.

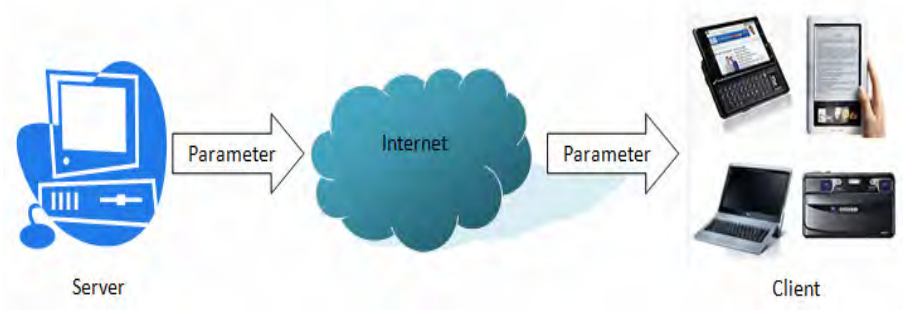

Figure 1. Sending data from server to client.

In the process, android based gadget will take data from website in form of weight, then it is used to predict weather data. On the application, it uses input of today's weather data to propagate the weight from learning process on the server side to forecast the weather data on *n*-day after to D day $(D + n)$. We are presented a block diagram of the training process on the system of weather data forecasting in Figure 2.

Conjugate gradient algorithm (Polak Ribiere, Fletcher Reeves and Powell Beale) is used in the ANN training and validation sets to determine the performance of ANN in the training process. This training process aims to obtain an optimal ANN architecture and its weights. Detailed explanation of backward propagation in the training process is presented in Figure 3.

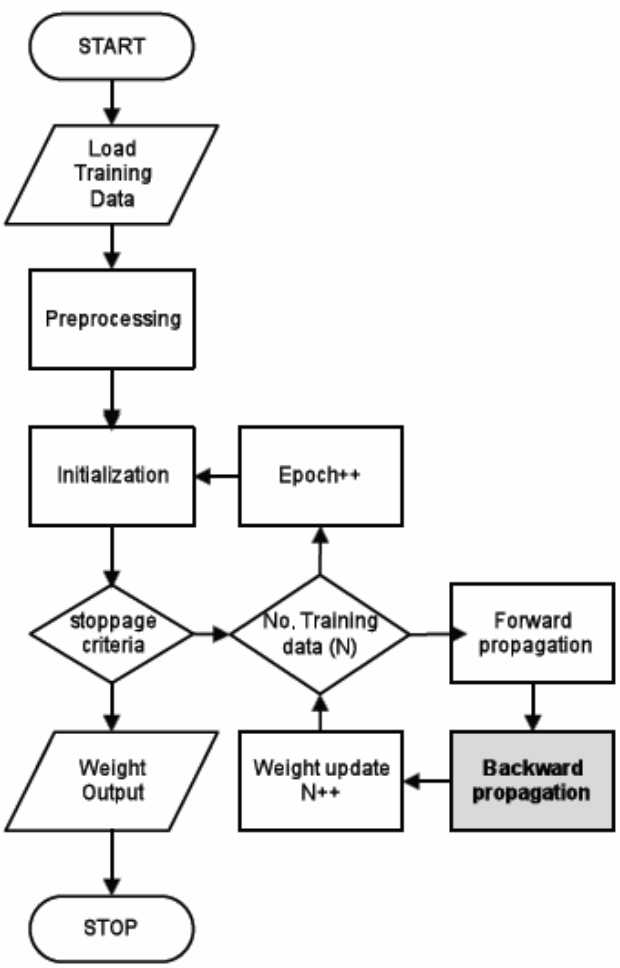

Figure 2. Block diagram of learning process.

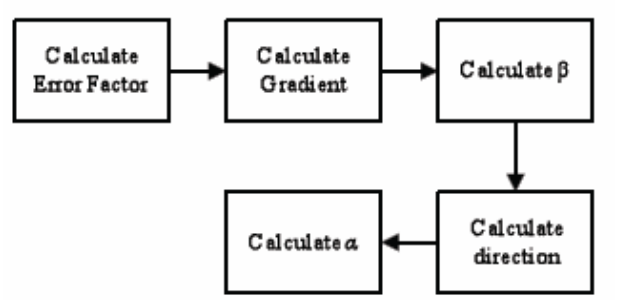

Figure 3. Backward propagation in learning process.

An important stage in the backward propagation is the selection method of learning rate which affects the weight. In [1], we have succeeded accelerate the backpropagation learning process combined with the conjugate gradient. In this paper, we analyze and implement a line search technique to conjugate gradient algorithm in the training process in backpropagation. This is an important point because the line search technique is used to analyze the parameter of the step size that can minimize time during the search direction. Figure 4 is served a block diagram of the system of weather data forecasting that can be implemented on the gadget.

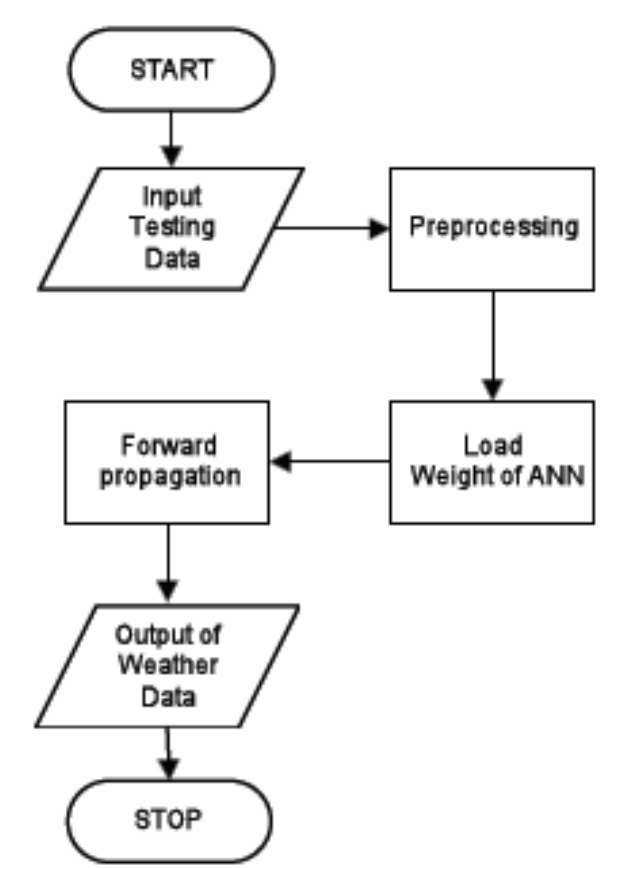

Figure 4. Block diagram of forecasting system.

4. The Results of System Testing

The testing result is explained as follows: The testing results show that accuracy of forecasting system is strongly influenced by the number of hidden neurons. We use small number of hidden neurons (5-20 hidden neurons), the testing result has relatively stable in accuracy. In Table I, we are presented some scheme of the ANN training process with the conjugate gradient algorithm to forecast the weather data. The scheme is depended on line search technique which is used in searching direction and how many the width of the steps taken in updating the weights.

Table I. Number of epoch for every scheme

Line search technique	Number of epoch		
	Temperature	Humidity	Air pressure
Brent's	30	5	10
Charalambous'	25	5	15
Golden section	5	5	10
Hybrid bisection-cubic	5	5	10

In [1], we show that backpropagation training which is modified by conjugate gradient algorithm needs about 40 epoch for a good accuracy in the testing. By using four schemes in Table I, line search technique which is implemented in modified backpropagation can improve the performance of training process. It just needs 5-30 epoch for the training process. This was due to line search technique affects search direction, the parameters α and β such that the training process converges quickly. Meanwhile, system performance of standard backpropagation needs more than 1000 epoch in the training process.

Next, we show the accuracy of forecasting system by using Mean Absolute Percentage Error (MAPE). The MAPE of temperature, humidity, and air pressure forecast results for each line search technique can be seen on Table II.

Table II. Error rate of forecasting result

Line search technique	Absolute error (%)		
	Temperature	Humidity	Air pressure
Brent's	2,07	7,53	0,08
Charalambous'	2,17	5,88	0,08
Golden section	1,90	8,29	0,07
Hybrid bisection-cubic	2,03	7,96	0,08

Based on the temperature, humidity and air pressure forecasting, the best technique of line search to use, to determine the value from parameter α on modified backpropagation, is Brent's search technique. Since the Brent's search technique is a searching technique of linearity using combination between golden section search and quadrate interpolation, where for this case, data which is given is suitable with the needs of step movements to be able to reach convergence rapidly. These results are smaller than standard backpropagation which has MAPE 3% of temperature forecast result and MAPE 8% of humidity forecast result.

Rainfall cannot be forecasted using this system properly. However, the six weather data is not sufficient to forecast rainfall in Jakarta, because rainfall data is affected the condition of El Nino and La Nina. This is due to El Nino and La Nina which are influence climate change and the level of rainfall in Indonesia as a maritime country. In subsequent research, we will develop a forecasting system that is able to forecast rainfall.

5. Conclusion

Generally, using technique of line search covering golden section, Brent's, hybrid bisection-cubic, and charalambous' gives the best performance in accelerating the time of backpropagation training. To determine the value of parameter α on modified backpropagation, the best technique of line search to use on forecasting of temperature, humidity and air pressure is Brent's search technique. The process of backpropagation training only needs small epoch (5-30 epoch). Forecasting system has a good performance, the MAPE is 2.5% for temperature, 7% for humidity, and

0,08% for air pressure forecasting. It is better than standard backpropagation which has 3% and 8% for MAPE of temperature and humidity forecast results, respectively.

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