Hybrid Machine Learning Model for Rainfall Forecasting

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Abstract

The state of the weather became a point of attraction for researchers in recent days. Its control in many fields as agriculture, the country determines the types of crops depending on the state of the atmosphere. It is therefore important to know the weather in the coming days to take precautions. Forecasting the weather in the future especially rainfall won the attention of many researchers, to prevent flooding and other risks arising from rainfall. This paper presents a vigorous hybrid technique that was applied to forecast rainfall by combining Particle Swarm Optimization (PSO) and Multi-Layer Perceptron (MLP) which is a popular kind used in Feed Forward Neural networks (FFNN). The purpose of using PSO with MLP is not just to forecast the rainfall but, to improve the performance of the network; this was proved by comparison with various Back Propagation (BP) an algorithm such as Levenberg-Marquardt (LM) through results of Root Mean Square Error (RMSE). RMSE for MLP-based PSO is 0.14 while RMSE for MLP-based LM is 0.18.

Keywords: Weather Forecasting; Feed Forward Neural Network; Levenberg-Marquardt; Multi-Layer Perceptron; Particle Swarm Optimization.

1. Introduction

The weather is the reflection state of the atmosphere around us, through its parameters such as temperature, wind, humidity, and other weather parameters [1]. It considers the main factor in many things as "Human" which affects the life of a human, controls the activities performed by humans and determines the wear based on the state of the weather. "Agriculture" the former determines the types of crops based on the weather, and its control of the plants that should be planted. So, weather forecasting has become an important field of research in recent days. Weather forecast is a vital process to avoid hazardous causes from the climatic [2].

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Weather conditions change rapidly and continuously. So, the process of forecasting needs suitable technique as Artificial Neural Networks (ANN). It is the most common use in forecasting weather, especially MLP because it has many benefits as solving nonlinear problems that can't solve by traditional techniques, extracting meaning from complicated or imprecise data, and learning how to perform a task based on data provided to train [3].

MLP used a gradient descent algorithm as BP is a supervised training algorithm. It trains MLP by adjusting the weights of each layer until the error between the desired output and the actual output is reduced [4].

Although BP has widely used for training MLP, it has drawbacks as the following [5]:

- Training is too slow which required many iterations to adjust weights so, that process takes a long time.
- Easy to fall into local minima where BP offers solutions for ANN through adapting the weights to reduce the error between desired and actual but, these solutions are not the best or optimal.
- Sensitivity to the choice of initial weights and biases where weights must select carefully because they affect the network and when the selection of weights and biases is not suitable that cause training process takes a long time and lead to the results cannot be optimal.

Usage of optimization algorithm based on Swarm Intelligent (SI). SI simulates the movement of animals in the swarm or searches space such as particle swarm optimization algorithm (pso) as a training algorithm for MLP instead of gradient descent BP to avoid the drawbacks mentioned above.

This paper aims to forecast the rainfall by applying the hybrid intelligent technique
MLP based on PSO.

The rest of this paper is represented as follows; Section 2 represents related work, Section 3 introduces techniques used in our research, Section 4 represents the proposed technique used for forecasting rainfall, and Section 5 represents experimental results and Discussion.

2. RELATED WORK

This section deals with some of the relevant works on our research topic that have been done on weather forecasting using ANN. ANN consider more accurate than other techniques such as Naïve Bayes, Decision Tree (DT), and K-Nearest Neighbor (KNN) through comparison between the techniques to treat huge data (Data Mining) DM [6]. FFNN was used to predict the minimum temperature for Jordan, using the actual data of 40 years for Arabia Weather in Jordan, data classified as 60% training, 20% validation, and 20% test [7]. BP algorithm is used for forecasting rainfall in the region of DELHI (India) through training FFNN [8]. Develop ANN (MLP) to forecast air temperature in the region of Meknes in Morocco based on weather parameters, such as atmospheric pressure, humidity, visibility, wind speed, and dew point; used LM training algorithm; observed Mean Square Error (MSE) is 3.65 when learning phase is 70% and testing phase is 30%, the value of MSE is the smallest value compared to other distribution of the database have been experimented [9]. Implement ANN with BP to forecast the weather for the next day by accepting input parameters of the previous day, ANN is a suitable technique that works on complex and nonlinear systems like Weather forecasting; 70 % of the dataset given as input to the network and 30% of the dataset is given as unseen to the network. The implemented network gives an error rate of 0.0773 of MSE and an accuracy of 90 % [10].

3. TECHNIQUES USED

3.1 Artificial Neural Network

ANN is a mathematical or computational model based on biological networks. It consists of interconnected artificial neurons and processes information using a connectionist approach to computation [11]. It is Like a human brain where knowledge is acquired by a network through learning and this knowledge is stored through interconnection strength called synaptic weight [12], [13].

ANN are consist of layers, each layer has a set of neurons are connected with each other through weights between the neurons. Data is mathematically processed and transferred results to neurons in the next layer. Neurons in the last layer provide the network's output [14]. In this case, ANN called MLP is the most common type used in FFNN and is known as a supervised neural network because it requires a desired output in order to learn. MLP need to learn how to do certain task through learning algorithm as gradient descent BP, Although BP is most important algorithm to train a neural network for weather forecasting, another learning algorithm has emerged faster and more efficiently than gradient descent called LM [1].

3.2 Levenberg-Marquardt

One of the most popular algorithms for non-linear problems; LM is another type of BP training algorithm that has been also used for ANN training. Although LM is more powerful than gradient descent techniques, it does not always guarantee a global optimum for the problem [11] as demonstrated by our comparison with PSO which will be clarified in the section on experimental results.

3.3 Particle Swarm Optimization

PSO developed by Kenndey and Eberhart in 1995, is a stochastic algorithm that describes the movement of animals as bird flocks and fish schools. Flocks of animals do not have a leader, but they follow one of them where its position close to the food source [15]. In the PSO algorithm, each particle in the population is reckoned as a solution that algorithm works on finding optimal values as work of birds flock and fish school. Each particle changes its velocity and its position according to the following equations:

$$v_i(t+1) = v_i(t) + c_1 r_1 \left(p_i(t) - x_i(t)\right) + c_2 r_{12} \left(p_g(t) - x_i(t)\right) \quad (1)$$

$$x_i(t+1) = v_i(t+1) + x_i(t) \quad (2)$$

Where Vi refers to the velocity of the particle i, t refers to an iteration number, c1, c2 refers to the learning rate for individual (local) and group (global), xi refers to the position of the particle i, pi, pg refer to local best for particle (personal best) and global best for the Particle(best particle) for a whole swarm, and r1,r2 refer to random values have values between (0-1) [15].

On each iteration of the algorithm, the current position considers a solution and if that position is better than the previous according to its value of fitness function which has a minimum value (minimize problem), that position considers Pbest [16]. Used inertia weight (w) to adjust the velocity of particles in the population, which provide particles to move close to each other where manage global exploration and local exploitation shown in the following equation (3) [17]:

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4. PROPOSED TECHNIQUE

Our proposed technique used for forecasting rainfall is represented in two steps:

First step: Develop ANN has the following feature as shown in the figure:

Input layer: has four nodes (neurons).
One hidden layer: has 20 nodes (neuron); although using two hidden layers get a more accurate and efficient result than one hidden layer, it takes a long time to train the network[18].
The output layer has one node (neuron).

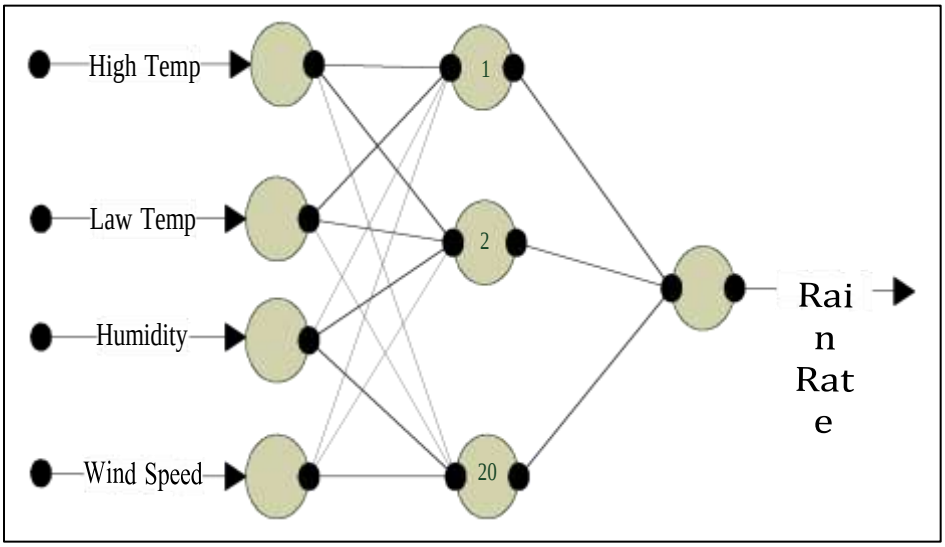

Figure 1: Artificial Neural Network

Second step: using an optimization algorithm based on stochastic search (PSO) instead of gradient descent (BP) to train the network, PSO avoids falling to a local minimum, because it is not based on gradient information as mentioned in the section of the introduction.

PSO generates weights where the dimension of the search space represents the total number of weights used to train developed ANN, the role of PSO in ANN is to get the best set of weights (particle position) and the role shows more through the following steps:

1. Initialize population size and maximum iterations for PSO.
2. Applied all particles to train constructed ANN and calculate fitness function (ff) (RMSE) to each particle in the population.
3. Determine personal best (Pbest) and global best (gbest) at each iteration which has the minimum value of RMS.
4. Other particles update their velocity based on gbest as equation (3) and position as equation (2).
5. Repeat step two and calculate ff to each particle; if current ff of the particle < pbest then current ff= pbest, otherwise pbest remain.
6. The pbest with the best value in all particles is set as gbest; after that repeat step four.
7. Repeat steps from two to six until reaching maximum iterations or reach zero.
8. After that, the best set of weights (particle position) that has the lowest value of RMSE for the whole swarm becomes known and set as gbest.

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9. After the training phase is finished, the testing phase starts with these weights used in the training phase to generate the final output of the network.

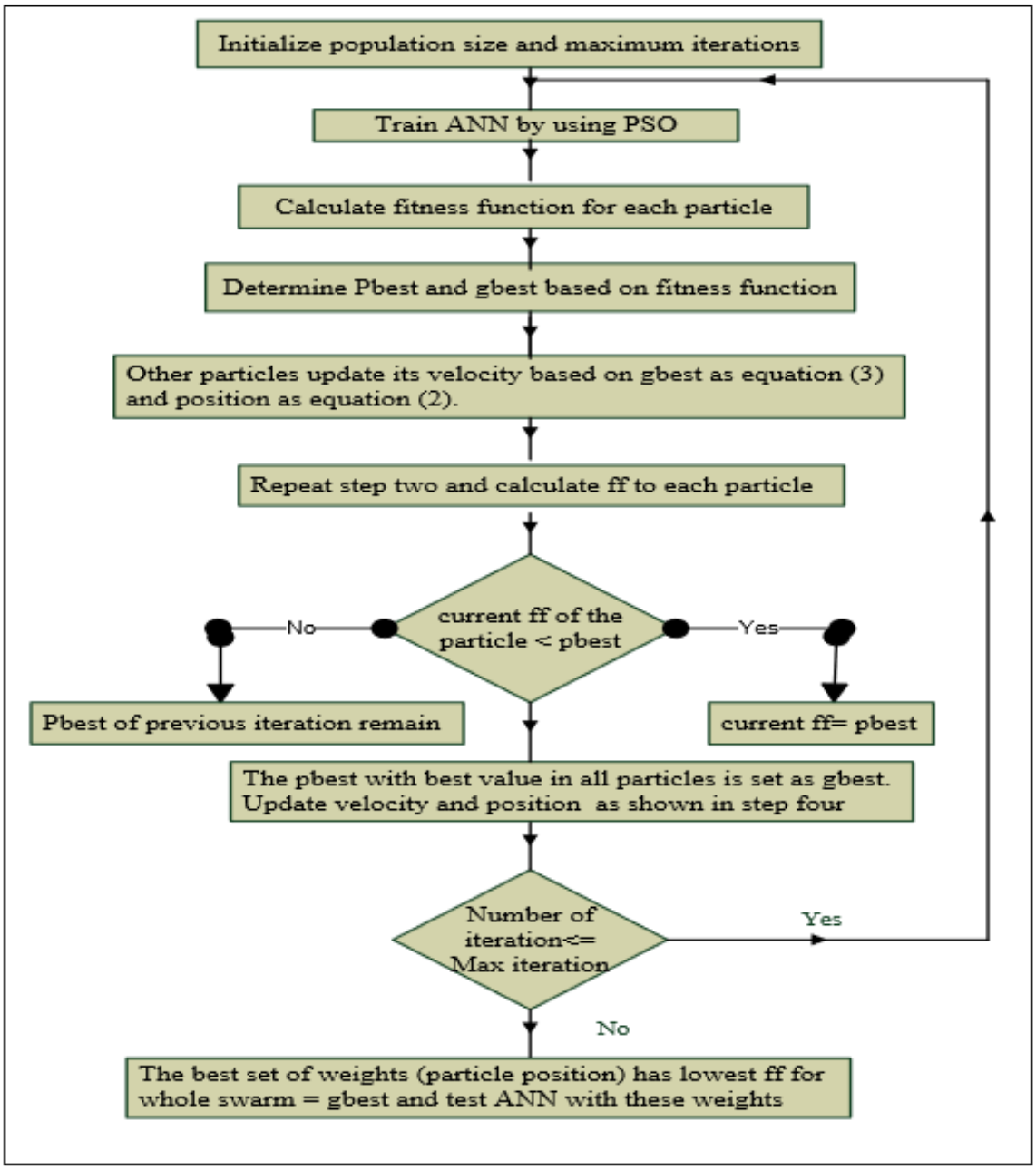

Figure 2: Artificial Neural Network-based Particle Swarm Optimization

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5. EXPERIMENTAL RESULTS AND DISCUSSION

5.1 Data Set

The constructed hybrid technique was applied to weather data of 2009 for New Capital Management through an astronomical site (Kottamia dome), the parameters of the weather are collected through the Automatic Weather Station (AWS). Consider law temperature, high temperature, humidity, and
Wind speed is the input parameter while rain rate is the output parameter that is the basis of our research to forecast.
Data is classified into two parts:-
The first part is the training phase used 90% of the data to train the network to forecast Rainfall.
The second part is the testing phase starts after the training is done successfully using to test the network using unseen 10% of the data.

5.2 Result and Discussion

In this section, the implantation of MLP for forecasting rainfall is introduced using two different training algorithms PSO and another version of BP LM.

5.2.1 Training Phase

In this phase used 90% of weather data to train two different techniques, as shown in figure 3.

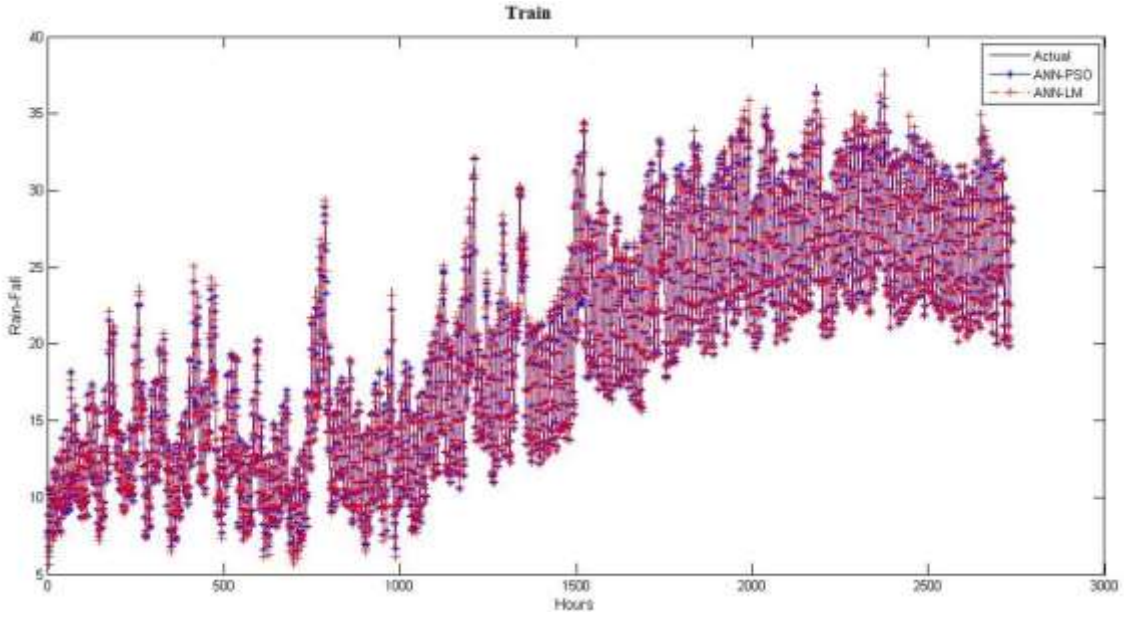

Figure 3: Training Phase for two training algorithms

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The values obtained from PSO as a training algorithm for MLP are more close to actual values of rainfall than the values obtained from LM as a training algorithm for MLP; that conclusion simulates the previous figure 3.

5.2.2 Testing Phase

This phase used 10% of unseen weather data to test two different techniques and their ability for forecasting, as shown in figure 4.

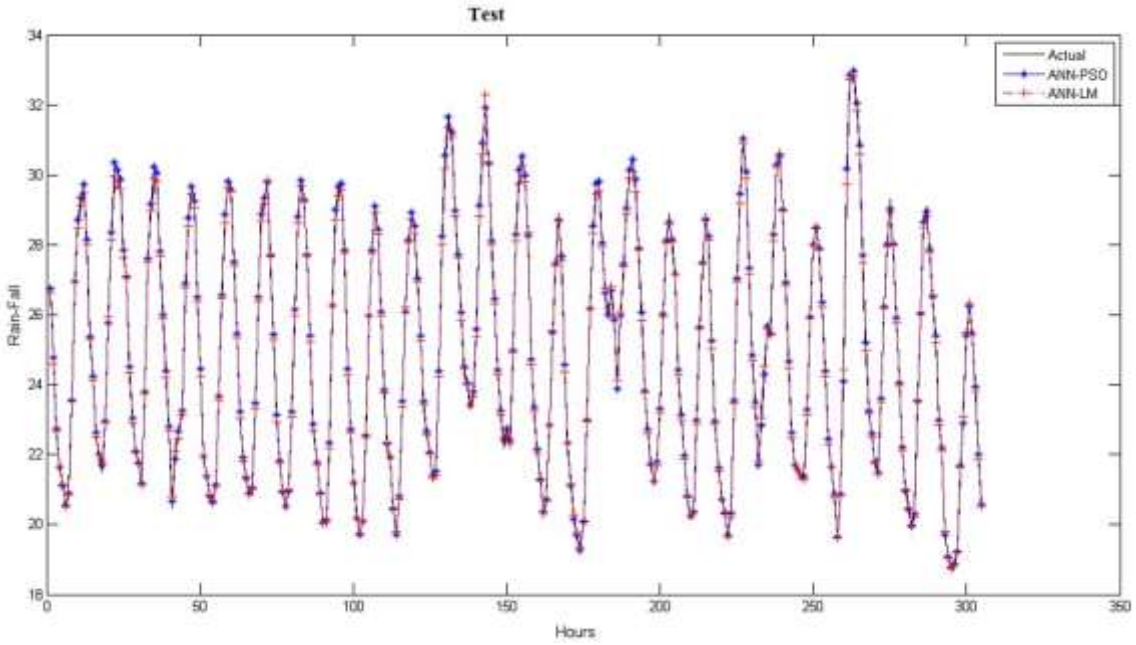

Figure 4: Testing Phase for two techniques

The values obtained from MLP-based PSO are more close to actual values of rainfall than the values obtained from MLP-based LM in the testing phase; as concluded in the training phase.

5.2.3 Performance of the network

Using a statistical method to measure the performance of the network, by measuring the error of each technique. The statistical method is RMSE as shown in table one.

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Table 1: Performance of two techniques

Techniques	**Training Phase**	**Testing Phase**
	RMSE	
MLP based PSO	0.12	0.14
MLP based LM	0.15	0.18

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6. Conclusion

ANN is one of the most suitable techniques used in data mining. Although ANN proved its efficiency, it suffers from some problems when using BP as a training algorithm. BP has some drawbacks mentioned in the previous; so, using a training algorithm based on stochastic to train ANN is more accurate than train ANN based deterministic. We proved it in the section on experimental results and discussion through the results of RMSE, MLP-based PSO is 0.14 while MLP-based LM is 0.18.

The proposed hybrid technique has two phases, in the first phase is developed neural network by determining the number of neurons for the input layer, neurons for the hidden layer, and several neurons for the output layer; in the second phase, PSO is mainly used for automatic generation of optimized weights which used in the first phase for a training network.

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