

# Forecasting Stock Price using Wavelet Neural Network Optimized by Directed Artificial Bee Colony Algorithm

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**Abstract**—Stock prediction with data mining techniques is one of the most important issues in finance. This field has attracted great scientific interest and has become a crucial research area to provide a more precise prediction process. This study proposes an integrated approach where Haar wavelet transform and Artificial Neural Network optimized by Directed Artificial Bee Colony algorithm are combined for the stock price prediction. The proposed approach was tested on the historical price data collected from Yahoo Finance with different companies. Furthermore, the prediction result was found satisfactorily enough as a guide for traders and investors in making qualitative decisions.

**Keywords**—Artificial Bee Colony algorithm, Artificial Neural Network, back-propagation algorithm, stock price forecasting, wavelet transform.

## 1. Introduction

The stock price prediction is one of the most important topics in finance and business. An intelligent system would predict the stock price and give a guide to investors to buy a stock before the price rises, or sell it before its value declines. Though it is very hard to replace the role of experts, an accurate prediction algorithm can directly result in high profits for investment companies. The efficient algorithm can also indicate a direct relationship between the accuracy of the prediction algorithm and the profit taken from the use of the algorithm. However, the stock market trends are nonlinear, uncertain, and non-stationary and nowadays it tends to be more risk than before for forecasting the stock price [1]–[3].

Artificial Neural Network (ANN) is one of data mining techniques being widely accepted in the business area due to its ability to learn and detect relationships among nonlinear variables. Several studies have shown that the ANN outperforms statistical regression models and also allows deeper analysis of large data sets, especially those that have the tendency to fluctuate within a short of period of time [4]–[7]. However, in the case of financial forecasting for enormous time series, appropriate data preprocessing techniques and optimization algorithms are required to enhance the accuracy of the predicted results.

In this study, the prediction system is built by the combination of preprocessing techniques including Haar wavelet and a neural network optimized by using Directed Artificial Bee Colony (DABC) algorithm [8]. The Haar wavelet is

utilized to decompose the stock price time series and eliminate noise, since the representation of a wavelet can tackle the non-stationary involved in the economic and financial time series [9]. The Artificial Bee Colony (ABC) algorithm is a novel meta-heuristic approach proposed by [10]. Due to the advantages of memory, multi-characters, local search, and a solution improvement mechanism, this algorithm can be used for identifying high-quality optimal solutions and offering the balance between complexity and performance, as well as optimizing predictions effectively. In this study, the DABC which is the improved version of the ABC is used to optimize the weights and biases of ANN before training the network by back-propagation (BP) algorithm. The main goal of this study is to figure out the efficiency of the ANN improved by using DABC for tackling the regression problem on a particular domain such as the stock market.

The remaining of the paper is organized as follows. Section 2 presents some works related to research fields. The proposed approach for the stock price prediction is shown in Section 3. Section 4 describes the experiments and obtained results. Conclusion and future works are presented in Section 5.

## 2. Related Works

Numerous researches about financial data mining have been done. Kim and Chun [11] implemented a neural network system using the technical analysis variables for listed companies in Shanghai Stock Exchange. They have compared the performance of two learning algorithms and two weight initialization methods. The results indicated that the forecasting of stock market is quite acceptable with both the algorithm and initialization methods, but the performance of the back-propagation can be increased by conjugate gradient learning and multiple linear regression weight initializations. However, when the structure of ANN gets to be complex and there are large training samples, convergent speed in these algorithms will become very slow. This influences the accuracy of the predicted results of ANN. To cope with this problem, a new method using the evolutionary algorithms is proposed in some researches [5], [12]–[14].

Kim and Han [15] used a genetic algorithm to transform continuous input values into discrete ones. The genetic

algorithm was used to reduce the complexity of the feature space. Kishikawa and Tokinaga [16] applied a wavelet transform to extract the short-term feature of stock trends. The past works have used various forecasting techniques in order to predict the stock market trends. Some methods attempted to forecast the daily returns, while some other studies developed forecasting models to predict the rate of returns of individual stocks. In many papers, it was also found that researchers have attempted to compare their results with other statistical tools. Each approach has advantages and disadvantages, so it is able to use one of them to hide the disadvantage of another. These findings provide a strong motivation for modeling forecasting tools for stock market prediction. Besides applying wavelet-based data preprocessing, this study uses the DABC algorithm to optimize the weights and biases of ANN to enhance the accuracy for results of the stock price prediction.

### 3. Methodology

In general there are two stock prediction methodologies: technical and fundamental analyses. Technical analysis using time-series analysis to deal with the determination of the stock price based on the historical data, while fundamental analysis concentrates on the forces of supply, the past performance of the company and the earnings forecast.

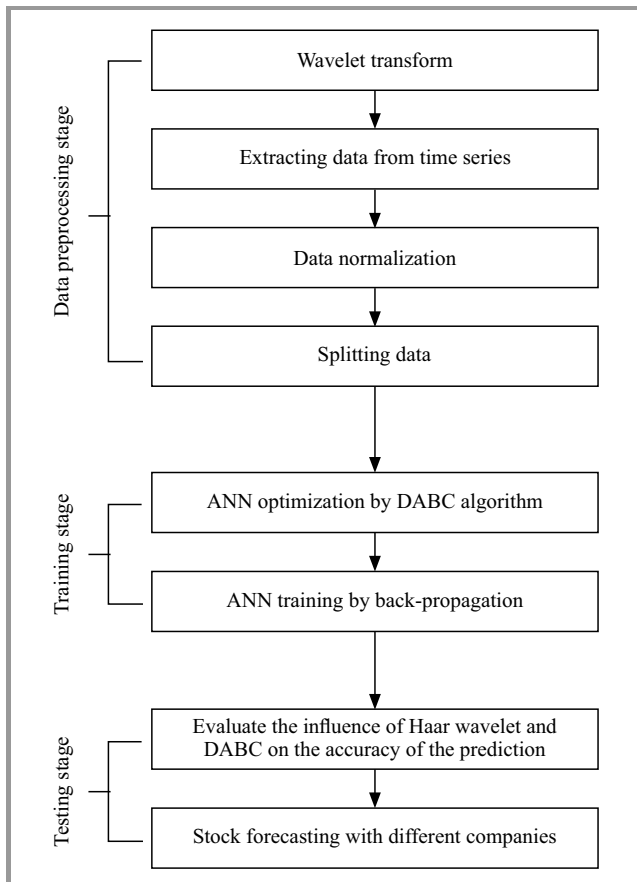


Fig. 1. Proposed approach overview.

To involve both fundamental and technical analyses, this study presents a novel approach that integrates the Haar wavelet transform and the DABC algorithm into the Multilayer Perceptron (MLP) neural network. Figure 1 briefly shows the main process used in this work and it will be explained in more details below.

#### 3.1. Choosing Data Formatting

The factors utilized for training the ANN are chosen based on the experience of trader with regard to the specific stocks. There are many technical indicators and fundamental factors such as: Moving Average (MA), Relative Strength Index (RSI), Boiling bands, Close/open prices, Volume oscillator being able to be used to analyze the stock market.

This work uses the close price to train the ANN, so the output of the ANN will be the close price as well.

#### 3.2. Data Preprocessing

##### 3.2.1. Noise Filtering Using Haar Wavelet Transform

The first stage of data preprocessing is the use of Haar wavelet to decompose the financial time series and remove noise since the representation of a wavelet can tackle the non-stationarity involved in the economic and financial time series [9]. Wavelets are mathematical functions that break data into various frequency components, and then each component is studied with a resolution matched to its scale. There are a wide variety of popular wavelet algorithms including Daubechies wavelets, Mexican Hat wavelets and Morlet wavelets. These wavelet algorithms have the advantage of better resolution for smoothly changing time series. However, they have the disadvantage of being more expensive to compute than the Haar wavelets. Therefore, this study uses the Haar wavelet which is the simplest algorithm and works well for the stock price time series.

A time series can be viewed in multiple resolutions when using wavelets. Each resolution represents a different frequency. The wavelet method computes averages and differences of a signal, breaking the signal down into spectrums. The Haar wavelet algorithm works on time series whose size is a power of two values (e.g., 32, 64, 128...). Each step of the wavelet transform generates two sets of values: a set of averages and a set of differences (the wavelet coefficients). Each set is half the size of the input data. For example, if the time series has 128 elements, the first step will generate 64 averages and 64 coefficients. The set of averages then becomes the input for the next step (e.g., 64 averages generating a new set of 32 averages and 32 coefficients). This process is repeated until one average and one coefficient are obtained.

The strength of two coefficient spectra generated by a wavelet calculation reflects the change in the time series at different resolutions. The first coefficient band shows the highest frequency changes. This is the noisiest part of the

time series. This noise can be eliminated by using threshold methods. Each later band reflects changes at lower and lower frequencies.

### 3.2.2. Extracting Data from Time Series

In the stock price prediction, authors have to decide that how many prices of the recent days will be used to predict the price of the next day. That value is called as “window-Size”. Traders can use any values for windowSize that they want, commonly in the range of 10 to 180 days.

This work uses 30-to-1 model that means using 30 recent days to forecast the next day. WindowSize is also the number of inputs used in the input layer of the ANN. To train the ANN, we need many 30-to-1 sequences, and each sequence consists of two vectors. The input vector includes 30 prices of 30 recent days while the output vector comprises the price of the next day. In order to obtain  $n$  sequences, we have to slide the window back  $n$  steps, and then extract one sequence at each step [7].

### 3.2.3. Data Normalization

Normalization is a process transforming the time series data points into a small pre-specified range generally from 1 to  $-1$  or 0 [17]. In order to facilitate the training process, the data needs to be normalized before training the ANN because the prices are in the different ranges. This study uses Vector Normalization [18] for normalizing data.

Mathematical formula of Vector Normalization is shown as the Eq. 1:

$$N_i = \frac{T_i}{\sqrt{\sum_{j=1}^k T_j^2}}, \quad (1)$$

where  $N_i$  is the normalized data and  $T_i$  is the time-series data,  $k$  is the number of values in series, and  $i = 1, \dots, k$ .

### 3.2.4. Splitting Data into Training, Validation and Testing Sets

One of the problems that occur during neural network training is called overfitting. In this case, the error on the training set is very small but when a new data is presented to the network, the error is high. In other words, the ANN performs well on training data and poorly on data it has not seen. This is due to the fact that the network has memorized the training samples but has not learned to generalize to new situations. The ANN will therefore not possess the generalization ability and will give a poor predictive performance.

For the purpose of resolving the overfitting problem, the data will be randomly separated into the training set and validation set. This is one of the simplest and most widely used means for avoiding overfitting [19]. The training set is the data set used to adjust the weights on the neural network. The validation set is used to minimize overfitting,

and the weights of the network associated with this data set are not adjusted during the training process. If the accuracy over the training set increases, but the accuracy over then validation set stays the same or decreases, then the ANN is overfitting and should stop training. The accuracy was evaluated by different errors, and in order to speed up the computation, authors ran the validation every 5 training epochs.

Note that the testing set is different with the validation set, because the validation data is independent of the training data. The testing set is used only for testing the final solution in order to confirm the actual predictive power of the network. Therefore, the testing set would be used to evaluate the prediction ability of the proposed approaches.

### 3.3. MLP Neural Network Setting

In general, the architecture of MLP-ANN can have many hidden layers and each hidden layer can include many neurons. However, theoretical works have shown that a ANN with one hidden layer is good enough to approximate any complex non-linear functions [17], [20]. In addition, many studies and experimental results also indicate that one hidden layer is sufficient for most of the forecasting problems [4], [17], [21]. Therefore, this work uses the architecture of MLP-ANN with one hidden layer.

Other difficult tasks when choosing good parameters for ANN are the number of hidden neurons and activation function. Setting a suitable architecture of the ANN for a particular problem is an important task, because the network topology directly affects to its computational complexity and generalization ability. Too much hidden layers or hidden neurons will drive the ANN to the overfitting. Based on conducted experiments and other researches [7], [22], the ANN with 8 neurons for the hidden layer and Bipolar Sigmoid function (Fig. 2) as activation function for both hidden and output layer is suitable for forecasting the stock price.

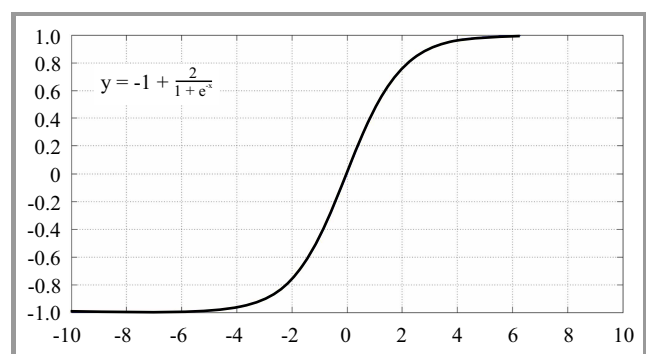


Fig. 2. Bipolar Sigmoid function.

Figure 3 shows the structure of the ANN used for proposed prediction system. The input layer is mapped with the input vector containing 30 (windowSize) latest close prices. The output layer including one neuron denotes the close price of the next day.

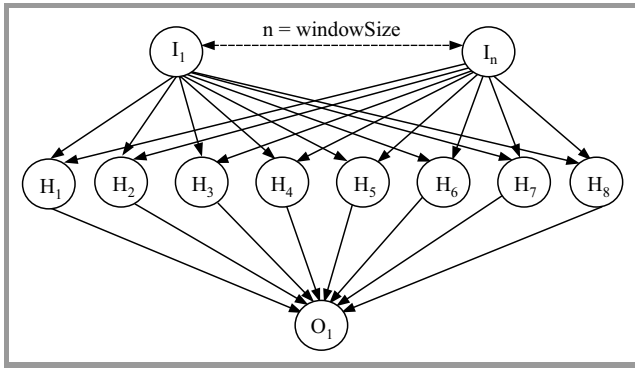


Fig. 3. The architecture of proposed ANN – windowSize-8-1.

It can be also known that the ANN structure also depends on the experience of trader and other factors, so proposed settings for ANN's parameters are just a recommendation for traders.

### 3.4. MLP Neural Network Training

After the data preprocessing process, the ANN will be trained via two stages. In the first stage, the weights and biases for ANN need to be optimized by using the DABC algorithm to overcome getting stuck in local optima. The DABC algorithm is an effective method for enhancing the convergence to global optimum [8]. In the second stage, the ANN with weights and biases being optimized by the DABC will be trained by back-propagation algorithm.

#### 3.4.1. Optimizing Weights and Biases of the ANN Using the DABC Algorithm

Artificial Bee Colony algorithm being one of the swarm intelligence algorithms is inspired by the foraging behaviors of real honeybee colonies. In ABC algorithm, a colony of artificial bees has three kinds of bees: employed bees, onlookers, and scouts. In this paper, a food source represents a possible set of optimized weights and biases for ANN. Employed bees will exploit a food source and then share information about their food sources with onlooker bees waiting on the dance area within the hive, while scout bees will randomly search for new food sources surrounding the hive to replace the ones abandoned by the employed bees. The details of the DABC algorithm are presented as Algorithm 1.

In this algorithm,  $fit_i$  is the fitness value of food source (solution)  $x_i$ ,  $v_i$  is the food source near  $x_i$ ,  $p_i$  is the probability value of  $x_i$ ,  $x_{ij}$  is the  $j^{th}$  dimension of  $x_i$ ,  $d_{ij}$  is the direction information of  $x_{ij}$ , and  $MCN$  is the maximum number of cycle in the algorithm. The number of employed bees is equal to the number of food sources. The employed bee whose trial counter is higher than the predefined limit becomes a scout bee.

After the data pre-processing process, the weights and biases of the ANN are initialized by using the directed ABC algorithm. The accuracy of the output of the ANN depends on its initial values of weights and biases. In this work, the

#### Algorithm 1: The pseudocode for DABC algorithm

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1: Load training samples
2: Generate the initial population  $x_i, i = 1, \dots, SN$  by using Eq. 4
3: Set the direction information  $d_{ij} = 0, i = 1, \dots, SN; j = 1, \dots, D$ 
4: Calculate the fitness  $fit_i$  of the population by Eq. 5
5:  $cycle = 1$ 
6: repeat
7:   for each employed bee do
8:     Produce new solution  $v_i$  by using Eq. 6
9:     Calculate the value  $fit_i$ 
10:    Apply greedy selection process
11:    Update the direction information
12:   end for
13:   Calculate the probability  $p_i$  for the solutions  $x_i$  by using Eq. 7
14:   for each onlooker bee do
15:     Apply Roulette Wheel to select a solution  $x_i$ 
16:     Produce a new solution  $v_i$  from  $x_i$ 
17:     Calculate the value  $fit_i$  of  $v_i$ 
18:     Apply greedy selection process
19:     Update the direction information
20:   end for
21:   If there is an abandoned solution for the scout then replace it with a new solution, which will be randomly produced by using Eq. 4
22:   Memorize the best solution so far
23:    $cycle = cycle + 1$ 
24: until  $cycle = MCN$ 
    
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DABC is used to seek the optimal set of initial weights and biases prior to the training process in order to enhance the convergence speed and the rigor of output values of the ANN. The process of optimizing the biases and weights is conducted by minimizing an objective function such as the mean square error given by Eq. 2:

$$E(\vec{w}_i(t)) = \frac{1}{N} \cdot \sum_{j=1}^T (O_j - Y_j)^2, \quad (2)$$

where  $T$  is the number of patterns in the training data set,  $E(\vec{w}_i(t))$  is the error at the  $t$ -th cycle in the algorithm,  $\vec{w}_i(t)$  is the vector of the weights of the ANN being included in the  $i$ -th individual at the  $t$ -th cycle,  $O_j$  and  $Y_j$  are the desired output and actual value of the  $j$ -th training data respectively.

At the beginning of the algorithm, the population is randomly generated and the direction information of all dimensions equals to 0.  $SN$  is the number of solutions, also the number of employed or onlooker bees. In this work, a food source or an individual represents a possible set of optimized weights and biases for the ANN. Each solution  $x_i$  is a  $D$ -dimensional vector containing weights and biases of the ANN. As for the proposed ANN architecture (windowSize-8-1), the value of  $D$  is the total number of weights and bias of the ANN that needs to be optimized and can be calculated by using Eq. 3 whose details are shown in Table 1:

$$D = IW\{1, 1\} + b\{1, 1\} + LW\{2, 1\} + b\{2, 1\}. \quad (3)$$

Table 1  
Parameters for proposed ANN (windowSize-8-1)

Value	Symbol	Description
WindowSize · 8	IW{1, 1}	Weights of the connections from input to hidden layers
8	b{1, 1}	Biases of neurons in hidden layer
8 · 1	LW{2, 1}	Weights of the connections between output and hidden layers
1	b{2, 1}	Biases of output neurons

After initialization, the population of the food source positions goes through repeated cycles,  $cycle = 1, 2, \dots, MCN$ , of three search processes for the employed bees, the onlooker bees, and scout bees phases. An employed bee searches around the current food source for a new food source and recalculates the nectar amount (fitness value) of the new food source. If the nectar amount of the new food source is higher than the previous one, the bee memorizes the new food source position and forgets the old one. Otherwise, it keeps the previous food source position. This is a greedy selection process. After all employed bees finish their neighborhood search, they share the nectar amount of the food sources and their position with the onlooker bees on the dance area. An onlooker bee assesses the nectar information given by all employed bees and selects a food source based on the probability associated with its nectar amount. Similar to the employed bee, the onlooker bee produces a new position and recalculates the nectar amount of the new position. It then applies the same greedy selection process as in the employed bee phase. In the initialization, a food source for employed bee is produced by using Eq. 4:

$$x_i^j = x_{min}^j + r \cdot (x_{max}^j - x_{min}^j), \quad (4)$$

where  $i \in \{1, 2, \dots, SN\}$ ,  $j \in \{1, 2, \dots, D\}$  and  $r$  is a random number in the range of  $[0 \dots 1]$ .

The fitness value is computed as Eq. 5:

$$fit_i = \begin{cases} \frac{1}{1 + f_i} & \text{if } f_i > 0 \\ 1 + abs(f_i) & \text{otherwise} \end{cases}, \quad (5)$$

where  $fit_i$  is the fitness of the  $i^{th}$  food source and  $f_i$  is the specific objective function value for the optimization problem. In this work,  $f_i = E(\bar{w}_i(t))$ .

In the DABC algorithm, a new food source position is generated by using Eq. 6:

$$v_{ij} = \begin{cases} x_{ij} + \varphi \cdot (x_{ij} - x_{kj}), & \text{if } d_{ij} = 0 \\ x_{ij} + r \cdot abs(x_{ij} - x_{kj}), & \text{if } d_{ij} = 1 \\ x_{ij} - r \cdot abs(x_{ij} - x_{kj}), & \text{if } d_{ij} = -1 \end{cases}, \quad (6)$$

where  $k \in \{1, 2, \dots, SN\}$ ,  $j \in \{1, 2, \dots, D\}$  are randomly chosen,  $k$  must be different from  $i$ ,  $abs$  is the absolute function,  $d_{ij}$  is the direction information for  $j$ -th dimension of the  $i$ -th food source position,  $\varphi$  is a random number in the

range of  $[-1 \dots +1]$  and  $r$  is a random number in the range of  $[0 \dots 1]$ . At the beginning of the algorithm, the direction information for all dimensions is set to 0. If the new solution obtained by using Eq. 4 is better than the old one, the direction information is updated. If the previous value of the dimension is less than the current value, the direction information of this dimension is set to  $-1$ , otherwise its direction information of this dimension is set to 1. If the new solution obtained by Eq. 4 is worse than the old one, the direction information of the dimension is set to 0. By this way, the direction information of each dimension of each food source position is used and the local search capability and convergence rate of the algorithm are improved as well [8].

An artificial onlooker bee selects a food source based on the probability value associated with that food source,  $p_i$ , computed by Eq. 7:

$$p_i = \frac{fit_i}{\sum_{n=1}^{SN} fit_n}, \quad (7)$$

where  $fit_i$  is the fitness value of the solution  $i$  and  $SN$  is the number of food sources.

After onlooker bee phase, if the trial counter is higher than the limit, a new food source position is randomly produced for this bee by using Eq. 4.

### 3.4.2. Training the ANN by Back-propagation Algorithm

After optimizing the ANN by using the DABC algorithm, the training process is continued with back-propagation algorithm to adjust the weights in the steepest descent direction (the most negative of the gradients). The ANN will be initialized with the optimized weights and biases in the first training phase and then back-propagation algorithm will be used to train the ANN for 50 cycles more.

## 4. Experiments

### 4.1. Evaluation Criteria

The proposed approaches were evaluated according to the root mean squared error (RMSE), the mean absolute error

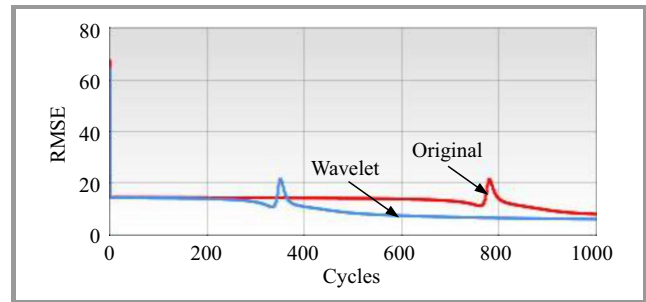


Fig. 4. RMSE of the training process with original data and noise-filtered data (GOOG).

Table 2  
RMSE, MAE and MAPE of the training process with original and noise-filtered data

Data	RMSE (USD)		MAE (USD)		MAPE	
Company	Original	Wavelet	Original	Wavelet	Original	Wavelet
AAPL	35.94700656	25.80857226	33.21142773	22.27953928	0.0622156017	0.0452399398
YHOO	5.608004908	4.593439167	4.940398152	3.990453741	0.1038292003	0.0846683761
GOOG	6.561397546	6.058494084	5.155632703	4.477504460	0.0096122608	0.0083394975

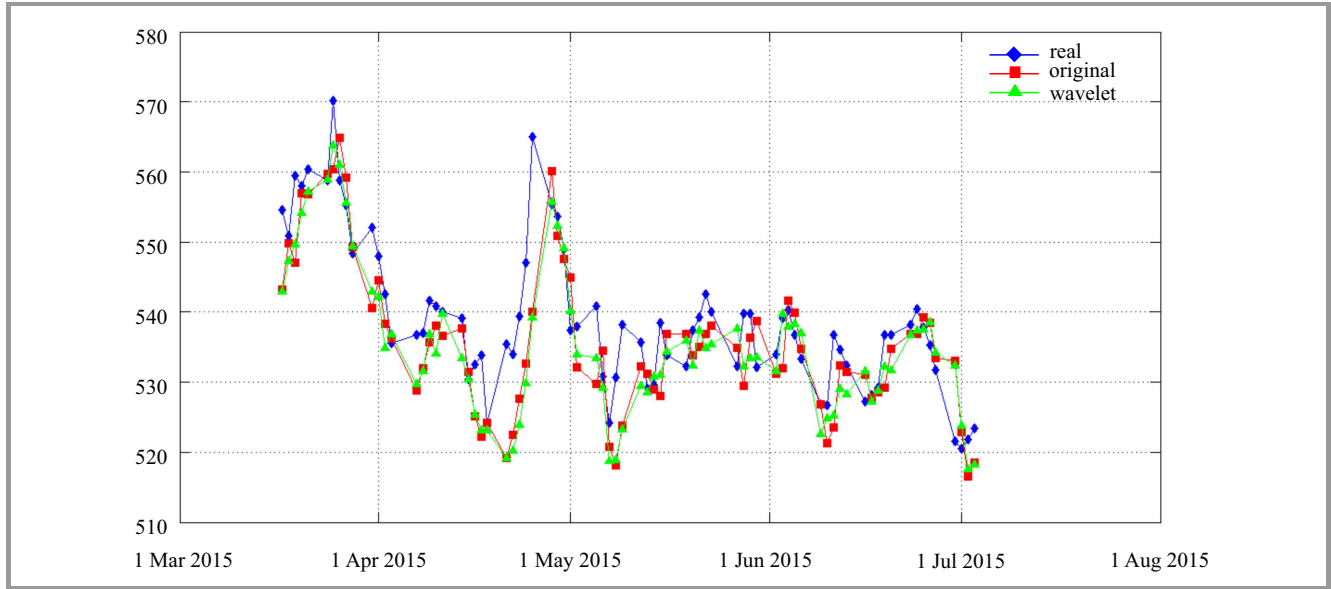


Fig. 5. Real close prices, close price predicted by ANN on original and noise-filtered data (GOOG).

(MAE) and the mean absolute percentage error (MAPE) criteria. These criteria are defined as :

$$RMSE = \sqrt{\frac{1}{N} \cdot \sum_{j=1}^N (O_j - Y_j)^2}, \quad (8)$$

$$MAE = \frac{1}{N} \cdot \sum_{j=1}^N |O_j - Y_j|, \quad (9)$$

$$MAPE = \frac{1}{N} \cdot \sum_{j=1}^N \left| \frac{O_j - Y_j}{Y_j} \right|, \quad (10)$$

where  $N$  denotes the size of testing sets.

These criteria measure how the predicted value  $O$  is close to the real value  $Y$ . The lower these measures are, the better result is. In this study, three these criteria will be used to assess the performance of the following experiments.

#### 4.2. Test Suites

The experiment system is implemented in C# .NET and evaluated on several historical prices data of different companies including the Apple (AAPL) in period 2009–2013, Yahoo! (YHOO) in period 2013–2014 and Google (GOOG) in period 3/2014–7/2015. These data were taken from the datasets in [23].

#### 4.3. The Accuracy of the Stock Price Prediction

As mentioned above, Haar Wavelet transform can eliminate noise. Therefore, it is suitable for handling highly irregular data series.

Using these data to train the network is better than the original data containing a lot of jags. The proof of the benefits of using wavelets is showed in Table 2, Figs. 4 and 5. The use of the Wavelet transform gave the lower error value and the faster convergence of neural network weights.

In this work, the DABC algorithm is used to optimize the network weights and biases by minimizing an objective function such as the root mean square error (RMSE)

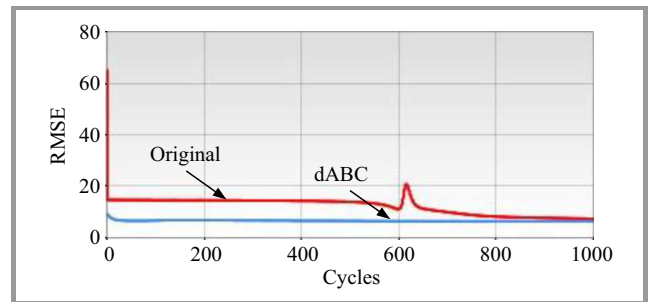


Fig. 6. RMSE of the training process with DABC-ANN and ANN without using DABC (GOOG).



Table 3  
RMSE, MAE and MAPE of the training process with DABC-ANN and ANN without using DABC

Data Company	RMSE (USD)		MAE (USD)		MAPE	
	ANN	DABC-ANN	ANN	DABC-ANN	ANN	DABC-ANN
AAPL	36.69341956	28.51912197	33.61652673	25.43316525	0.0692116977	0.0521619069
YHOO	5.559001606	1.272516355	4.644378052	1.047215288	0.1232102173	0.0259282003
GOOG	6.584116070	5.832372776	5.195642497	4.176874924	0.0093781278	0.0077784335

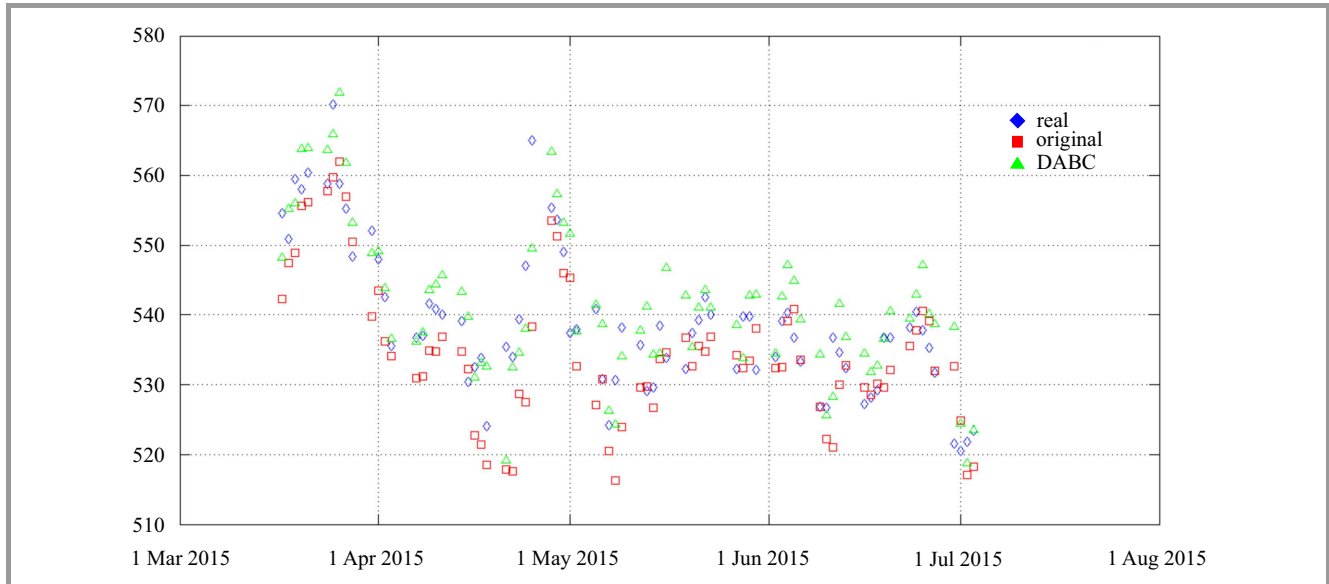


Fig. 7. Real close prices, close price predicted by DABC-ANN and ANN without using DABC (GOOG).

given by Eq. 8. The optimal set of weights and biases found by DABC was used in the next training process of the ANN using back-propagation algorithm. The use of DABC for the optimization of weights and biases gave the lower error value and the faster convergence of neural network weights. Table 3 and Fig. 6 take a proof of the influence of the DABC-ANN model and the ANN (without using the DABC) model. The DABC-ANN gives the lower values through different testing sets. The reduction of values of the criteria given by Eqs. 8–10 is 36.66% on average for three testing data sets. Figure 6 also shows that the RMSE of the DABC-ANN forecasting model converges faster than that of the ANN model. Those figures indicate that the DABC optimization gives the prediction result more accuracy, and it also speeds up the second training stage by reducing the number of training cycles. Figure 7 shows the forecasting results of the DABC-ANN and ANN models and how these prediction values are close to the real values.

**4.4. The Prediction Results of the Proposed Approaches**

For more accurate in the evaluation of the ANN, each fact possesses a different proportion of training-validating/test set. For the Google in period 2014–2015, the sub-datasets for the first twelve-month period are used for the training-validating process, while those from 3/2015 to 7/2015 are

selected for testing. With regard to the Apple and Yahoo, the first ten-month period (87%) is used for the training-validating process and the next two-month period for testing. The statistical meritorious results of testing process are shown in forecasting figures from Fig. 8 to Fig. 10.

**4.5. The Execution Time**

In this work, the complexity of algorithms depends on the configuration parameters of DABC algorithm and ANN network as well as the size of input values (window sizes). The authors have conducted the experiments and recorded the average time of 20 execution times on each dataset as shown in Table 4. The training data set of Apple is collected in period 2009–2013, Yahoo data set is taken from the period of 2013–2014 and Google data set is in the period from 3/2014 to 7/2015.

Table 4  
Execution time of experiments

Data Company	DABC optimization [s]	ANN training [s]	Total [s]
AAPL	124	3	127
YHOO	30	4	34
GOOG	37	3	40

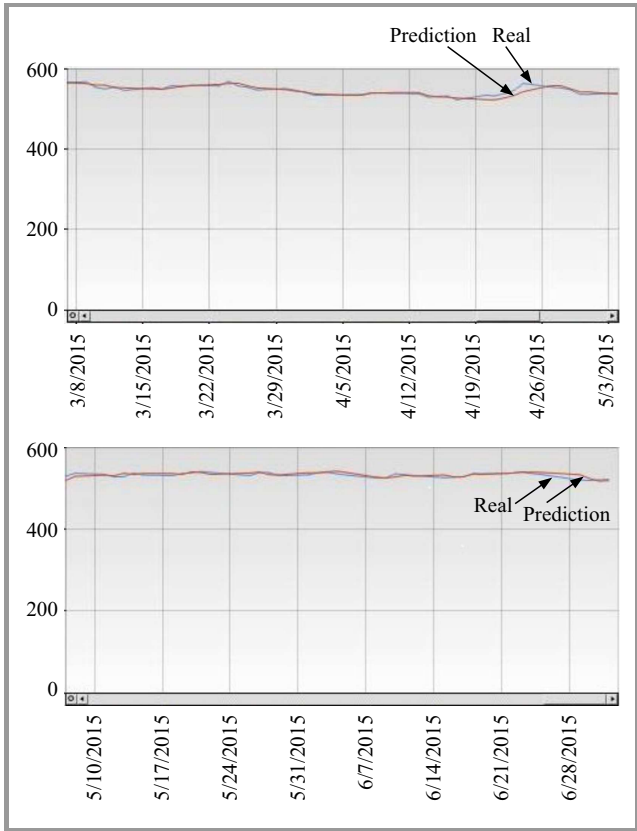


Fig. 8. Testing result of DABC-ANN for Google for period 3/2014–7/2015.

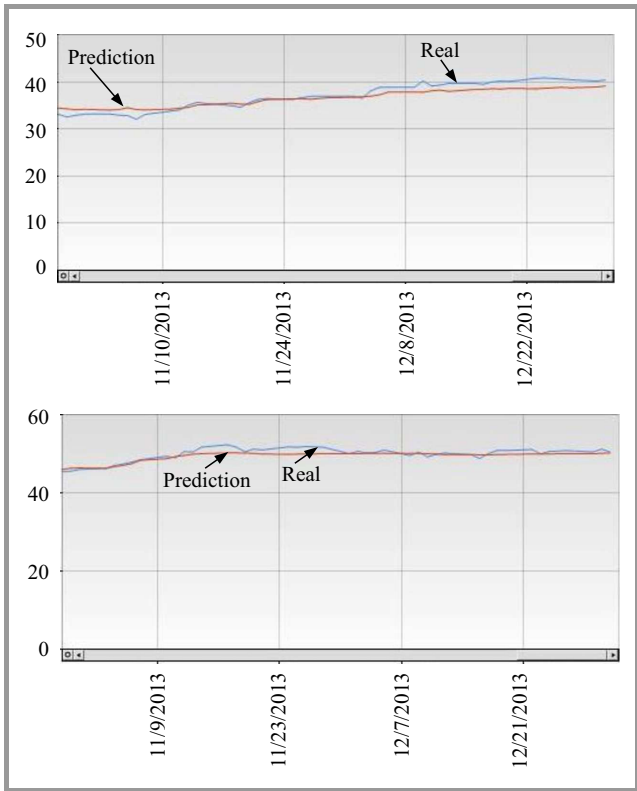


Fig. 9. Testing result of DABC-ANN for Yahoo for period 2013–2014.

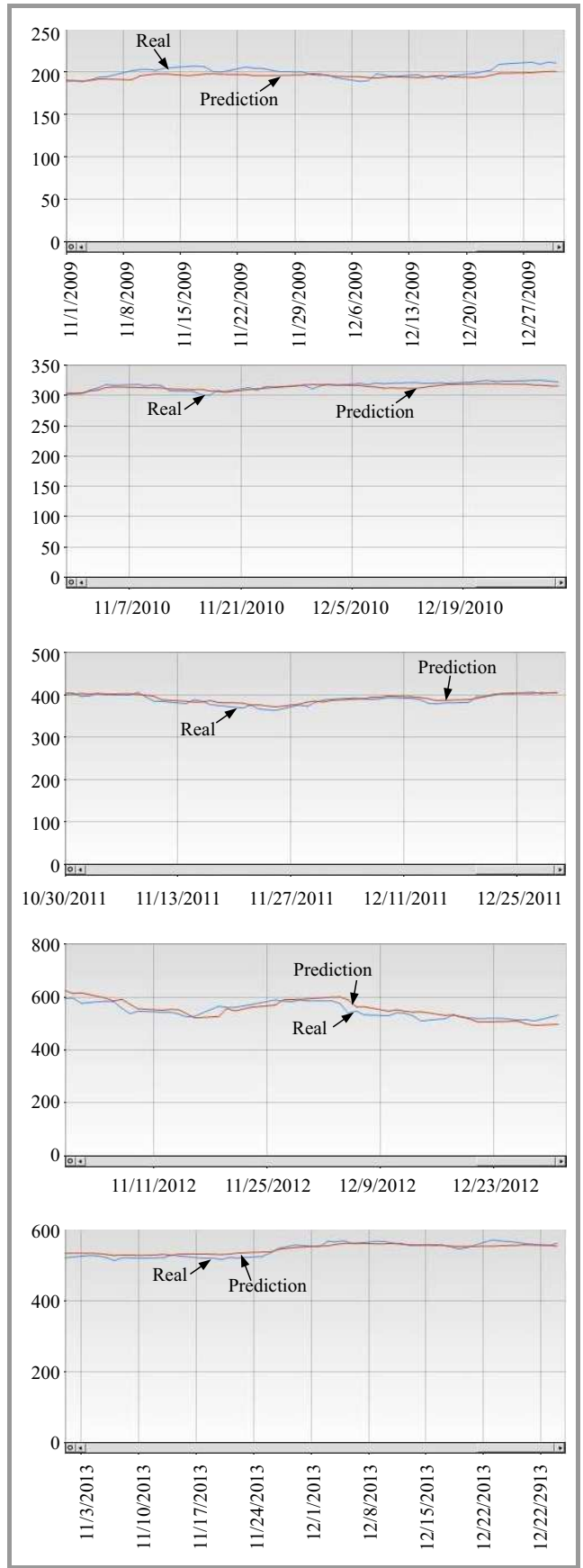


Fig. 10. Testing result of DABC-ANN for Apple for period 2009–2013.



It can be stated that such computation time might meet the requirements of scalping systems in which length of the time window is 15 minutes or even less in the real world when the proposed approach is applied to the value of time windows being less than 15 minutes.

## 5. Conclusion

Although artificial neural networks have the positive performance in terms of mining non-linear data with self-learning ability, stock forecasting still requires a more reliable method to integrate a precise training process into the neural networks. This study proposed a hybrid approach of the data preprocessing techniques and optimized algorithms with the multilayer feed-forward neural network trained by back-propagation algorithm to create a predictive model for enhancing the accuracy of stock prediction. Haar wavelet transform utilized to decompose the stock price time-series and eliminate noise. Directed Artificial Bee Colony algorithm, which is the improved version of ABC algorithm, was used to optimize the weights and biases for the ANN in the first stage of training process.

Though the proposed integrated system has a satisfactory predictive performance, it still has some insufficiencies. Future work tends to determine the critical impact of specific fundamental analysis variables on the quality of the stock price prediction. In addition, a more advanced pattern selection scheme might be embedded in the system to retrieve significant patterns from the data.

It can be seen that the prediction process of stock prices is usually affected by 4 factors including open, close, high, and low prices, in which the close price was used in this study with the promising results. In reality, open price is not used very often, however low and high price may be crucial, so authors will consider the using these two values in the further studies. This work employed 30-to-1 model that means using 30 recent days to forecast the next day. This value seems to work quite well, but in some different technical analysis indicators the value of 14 is commonly used for the window size. Therefore, we plan to carry out many experiments to assess the influence of window sizes on the accuracy of the stock price prediction problem.

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