An enhanced artificial neural network for stock price predications

Jiaxin Ma
Silin Huang
S. H. Kwok
The Hong Kong University of Science and Technology
Hong Kong SAR

Keywords
Artificial Neural Network (ANN), Min-Max Normalization, Iterative Approach, Stock Price Predication

Abstract
Predicting stock price of a particular stock is a difficult non-linear problem. Artificial Neural Network (ANN) is a tool to solve this kind of problem and has received much attentions in the field of financial modeling in recent years. This paper proposes an enhanced ANN for predicting stock prices with a novel Max-Min normalization method as well as an iterative approach. Our experimental results confirm that the predication accuracy outperforms other existing ANN predication mechanisms.

1. Introduction

Stock price prediction is one of the most important topics in finance and business. However, the stock market is highly changeable and unpredictable. Fundamental analysis and technical analysis are two main schools of approaches trying to solve the problem from different perspectives. Unlike fundamental analysts who look into the intrinsic implications of the stock indicators, technical analysts evaluate stocks based on patterns or trends recognized from data analysis. One of the novel, yet highly discussed techniques is Artificial Neural Network (ANN). With the ability to solve complex such as nonlinear and stochastic problems with simple computational operations as well as the self-organizing feature (Daniel Graupe, 2013), ANN is progressively considered as one appropriate approach for stock price prediction.

Though much work has been done on finding the best configuration of ANN for stock price forecasting, little attention has been given to data pre-processing and training-testing set division. This paper aims at proposing an enhanced ANN to improve prediction accuracy by adopting a new Min-Max normalization method as well as the iterative approach with fewer inputs. The proposed ANN was tested with stock price data of the Hong Kong and China Gas Company Limited (0003.HK).

2. Proposed Artificial Neural Network

The objective of the proposed ANN is to predict the closing price of a given stock, and to modify the existing ANN model to increase the prediction accuracy.

The performance of the ANN model mainly depends on the data processing method, neural network configuration and network training approach. The proposed ANN is presented in Table 1.

(1) Data collection
(2) Choose appropriate network architecture and algorithm. Multi-layer perception model trained with back propagation algorithm was primarily chosen
(3) Determine the data pre-processing (cleaning and normalization) method
(4) Choose appropriate network configuration (number of hidden layers, number of hidden neurons)
(5) Adopt the Iterative approach
(6) Perform the training and testing for each cycle
(7) Choose the network with the smallest MSE results among all the tested cycles

Table 1: Algorithm for the proposed ANN.

a) Data Collection

The dataset used in this paper is extracted from daily data of the Hong Kong and China Gas Company Limited (0003.HK), also known as "Towngas", which is the first public utility in Hong Kong and currently one of the Hong Kong's largest energy suppliers. As one of the constituents of the Hang Seng Index (Hang Seng Indexes, 2016), it is considered to be a typical stock in the Hong Kong stock market, and thus it is more likely that the methodology used for it can be further applied to other similar stocks in Hong Kong.

The dataset contains the date, opening price, daily highest price, daily lowest price, closing price, daily transaction volume and adjusted closing price of the stock in every trading day from 2014-01-01 to 2015-12-31. The data was collected from the website of Yahoo! Finance (Yahoo! Finance, 2016).

b) Basic Architecture and Algorithm

This paper adopts resilient back propagation for the optimization of neural network (Anastasiadis, Magoulas & Vrahatis. 2005). The logistic function was chosen for the activation function and the sum of squared errors was used as the error function. In the training process, the number of repetitions for training was set to be 5. The maximum step of the training is set to be 10^5

c) Data Pre-processing

i. Cleaning of Incomplete Data

To ensure the overall prediction accuracy, the daily data containing missing entries should be removed from dataset. The database selected for this research contains daily data with zero volume possibly because of company's restructuring operation or other issues. They were removed from the dataset. After cleaning those incomplete data, there are data of 494 trading days remaining in the dataset.

ii. Data Normalization

For data normalization, the Max-Min normalization method was adopted to the training set, and the scaling range of [-1/2, 1/2] was used. The function used is:

$$i = \frac{i' - \text{center}(i')}{\text{scale}(i')} = \frac{i' - \frac{\max(i') + \min(i')}{2}}{\max(i') - \min(i')}$$

where i = a normalized value

i' = value to be normalized

max (i') = maximum value of the variable series to be normalized

min (i') = minimum value of the variable series to be normalized

d) Network Configuration

The proposed ANN uses a three-layer multilayer neural network model with one 5-node input layer, one 5-neuron hidden layer, and a single node output layer as shown in Fig. 1

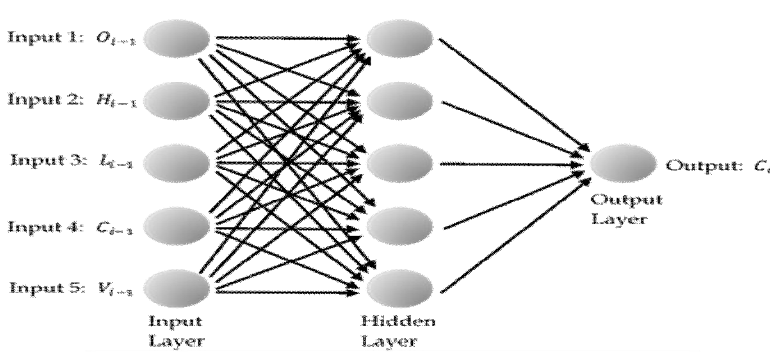

Figure 1: Neural network configuration with three layers.

According to the objective of the proposed ANN, the output variable is the closing price of day i(C_i). According to the findings from the literature review, five basic daily stock parameters were considered as input variables, which are: O_{i-1}: opening price of day (i – 1); H_{i-1}: the highest price of day (i – 1);L_{i-1}: the lowest price of day (i – 1); C_{i-1}: closing price of day (i – 1); and V_{i-1}: transaction volume of day (i – 1).

e) Iterative Training Approach

To fully utilize the given data, an iterative training approach is proposed for training. The length of the training set is fixed to be 474 days, while the length of the testing set is 1 day. The testing set starts from 2015-12-03. In other words, the closing price for 2015-12-03 is predicted using the training result of 474 trading days right before it. In the end of 2015-12-03, when its exact closing price is known, the training set is updated by adding the latest observation in 2015-12-03 and discarding the oldest one. Thus the new training set for the prediction of 2015-12-04, is the previous 474 days. For the particular dataset selected for this paper, the data of the last 20 trading days were to be predicted. The remaining daily data were used at least once as training data. Before the iterative training process, the series of the input variables in the training set were normalized. The input data in the testing set were scaled according to the training set.

3. Experiments

a) Measurement Criteria for Network Performance

The network performance is assessed mainly by prediction accuracy. Each neural network was first trained for 5 times. In each trial, the mean squared error (MSE) of the de-normalized predicted closing price was calculated. The prediction accuracy was measured by the mean and the standard deviation (SD) of the five-trial MSEs.

$$\text{MSE} = \frac{1}{n} \times \sum_{i=1}^{n} (\hat{C}_i - C_i)^2$$

where n = the number of the predictions in the testing set

$\hat{C}_i$ = the de-normalized predicted closing price of day i

C_i = the actual closing price of day i

$$\text{Mean} = \frac{1}{m} \sum_{j=1}^{m} MSE_j$$

$$\text{SD} = \sqrt[2]{\frac{\sum_{j=1}^{m} (MSE_j - Mean)^2}{m-1}}$$

where m = the number of the training trials

MSE_j = the MSE of the trial j

b) Comparison with Existing Model

In our experiments, six different combinations of two commonly used normalization methods (Max-Min method and Z-score method) with three different scales ([-1/2,1/2], [-1,1], [0,1]) were tested. The dataset we used was a two-year (2014-03-31 to 2016-03-30) daily data of Towngas, with the first 95.94% (472 days) being the training set and the last 20 days is the testing set. For all the 6 combinations, the network structure of 6 inputs, 1 output with 1 hidden layer was constructed. Inputs were O_{i-1}, H_{i-1}, L_{i-1}, C_{i-1}, V_{i-1} and A_{i-1} respectively, where

A_{i-1} represents adjusted closing price of day (i - 1). Output was C_i. Different numbers of nodes (6, 12, 18 or 24) in the hidden layers were tested. For Max-Min method, calculation was performed according to Table 2.

Normalized Training-set Range	Center	Scale
[-1, 1]	$\frac{\min(i) + \max(i)}{2}$	$\frac{\max(i) - \min(i)}{2}$
[-1/2, 1/2]	$\frac{\min(i) + \max(i)}{2}$	max(i) – min (i)
[0, 1]	min(i)	max(i) – min (i)

Table 2: Max-Min normalization method with three scales ("i" refers to each input variables).

For Z-score method, raw data was first normalized. After pre-normalization, Max-Min normalization method was then used to scale the data to the range of [-1/2,1/2] , [-1,1] and [0,1] respectively.

Normalized Training-set Range	1st Normalization			2nd Normalization	
	Center	Scale	Pre-normalized Training-set Range	Center	Scale
[-1, 1]	Mean of i	SD of i	S = [a, b]	$\frac{\max(S) - \min(S)}{2}$	$\frac{\max(S) - \min(S)}{2}$
[-1/2, 1/2]	Mean of i	SD of i	S = [a, b]	$\frac{\min(S) + \max(S)}{2}$	max(S) – min(S)
[0, 1]	Mean of i	SD of i	S = [a, b]	min(S)	max(S) – min(S)

Table 3: Z-score normalization method with three scales.

In each combination, we set 6, 12, 18 and 24 as the number of hidden-layer neurons respectively and found out the best configuration that gives the best MSE. The result for each combination is shown in Table 4. In this table, configuration is displyed in the form of "number of inputs – number of hidden-layer neurons – number of outputs". For example, 6-12-12-1 represents the network with 6 inputs, 2 hidden layers containing 12 neurons in each hidden layer and 1 output.

Normalization Method	Normalized Training-set Range	Best Configuration	Mean of 5-trial MSEs	SD of 5-trial MSEs	Comments
Max-Min	[-1, 1]	6-6-1	0.17649292	0.01174585	
Max-Min	[-1/2, 1/2]	6-6-1	0.16306232	0.00273675	Smallest MSE
Max-Min	[0, 1]	6-12-1	0.16490424	0.00570716	
Z-Score	[-1, 1]	6-6-1	0.16628546	0.00930811	
Z-Score	[-1/2, 1/2]	6-6-1	0.16390940	0.00492479	
Z-Score	[0, 1]	6-6-1	0.16932494	0.00875395	

Table 4: Results for different normalization methods and scales.

Table 4 shows that all the 6 combinations perform similarly. However, the Max-Min normalization with the scale of [-1/2,1/2] gives the best combination of mean and SD of MSEs. Thus we will adopt the Max-Min normalization with scale of [-1/2,1/2] in our model.

Forecast performance is shown in Table 5 for the same training and testing set using two methods – without consideration of iteration and the purposed iterative training approach.

Method	Window size	Configuration	Mean of 5-trial MSEs	SD of 5-trial MSEs
Without iteration	1 day	5-5-1	0.01031	0.0008352
Iterative Approach	1 day	5-5-1	0.00968	0.0008228

Table 5: Forecast performance.

According to Table 5, it can be concluded that the iterative training approach gives better prediction results. However, for predicting the same 20 days, the iterative approach takes longer time.

4. Conclusions and Future Works

This paper proposed an enhanced ANN to predict the closing price of a stock in the Hong Kong stock market. Prediction of the stock closing price of the next day was modeled using a three-layer neural network trained with back propagation function. The paper enhanced existing neural network models to increase the prediction accuracy. The major contribution of this paper is to advance the normalization method and the training approach. For data normalization, the Max-Min normalization method was adopted and the scaling range were proposed to be [-1/2, 1/2]. For the training process, this paper proposed the iterative training approach, which limits the testing set length to be 1 day and kept updating the given data information while training the network. To compare with the existing model and to assess the prediction performance of the proposed model, empirical implementation was conducted on the stock of the Hong Kong and China Gas Company Limited (0003.HK). The mean and standard deviation of the MSEs obtained from the 5-trial trainings in every pair of comparison were used to measure and analyze the model performance. The empirical results show that the proposed ANN performs better with a higher level of prediction accuracy. A possible explanation for this is that the proposed normalization method keeps the distribution of the original data unchanged after scaling, and that the relatively small scaling interval contains both positive and negative values, which could make the data information more sensitive for prediction. And the iterative training approach also ensures that network training can make full use of the latest updated data information to provide more accurate prediction results. In conclusion, the application of the proposed model to the prediction the stock's closing price of the selected database has demonstrated its potential to be used in other stocks in Hong Kong stock markets. It will play a supportive role in helping investors make decisions in the stock market to achieve better prediction.

Since stock price is sensitive to many factors, five basic input variables used in the proposed model might not provide enough information for prediction. For future studies, we will introduce more input variables and figure out a better combination of the input sets. Potential input variables may include technical indicators, such as SMA (simple moving average), EMA (exponential moving average), MACD (moving average convergence), etc. Fundamental indicators like exchange rate and price per annual earning might be considered as well.

References

Anastasiadis, Magoulas &Vrahatis., 2005. New globally convergent training scheme based on the resilient propagation algorithm. *Neurocomputing*, [e-journal] 64. 253-270. Available through: ScienceDirect website <http://www.sciencedirect.com/science/article/pii/S0925231204005168> [Access 8 May 2016].

Graupe, D., 2013. *Principles of Artificial Neural Networks*. 3rd ed. Singapore: World Scientific Publishing Company.

Hang Seng Indexes, (2016). Hang Seng Index and Sub-indexes. [online] Available at: http://www.hsi.com.hk/HSI-Net/HSI-Net [Accessed 9 May. 2016].

Yahoo! Finance, (2016). Historical Prices. [online] Available at: http://finance.yahoo.com/q/hp?s=0003.HK+Historical+Prices [Accessed 2 Apr. 2016].