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Neuro-Fuzzy System Optimized Based Quantum Differential Evolutionary for Stock Market Forecasting

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Abstract: ***The main objective of this paper is to predict the gold price in the Forex market, it introduces the use of Quantum Differential Evolution Algorithm in a Neuro-fuzzy system composed of an Adaptive Neuro-Fuzzy Inference System (ANFIS) controller used in prediction of stock market, specified by an optimization technique based on a double chains quantum differential evolution algorithm, to evaluate the proposed model three performance measurements are used: Root Mean Squared Error (RMSE), percentage error and Mean Tendency Error (MTE). The algorithm was evaluated with actual financial data and proved the weakness of the comparative method by showing much improved and better predictions by finding the best value for optimization variable in ANFIS using a double chains quantum differential evolution algorithm.***

Keywords: Fuzzy logic, Neural network, Stock market prediction, Neuro – Fuzzy, Differential evolution, Quantum evolutionary.

1. INTRODUCTION

The main aim of this paper is to predict the gold price using price history affected by many economic factors. [1] Usually the main goal of many investors is getting a trustworthy prediction method for the stock market, this goal can be achieved with the aid of econometric concepts, statistical methods and technical analysis, that was what motivates many researchers to think up new models and methodologies to forecast. in the last decades artificial intelligence was found to provide valuable results for problems. [2]The attitude of the stock market could be predicted using historical inputs; this is the concept beyond Technical Analysis of Investment trading. Thus, there is a function

$$R(z)=f(r(z-j),l,s) \quad (1)$$

whereR(z) is the day stock price, r(z-j) is the stock price for the days that preceded the day while l and s are the other effective factors like daily lowest value, daily highest value, open value of the price and volume of trading, ... etc. Thus, forecasting the future price of the stock converts to the problem of regression data in the perspective of computer science [3].Many valuable models are implemented to solve this problem in computer science and operation research. from them artificial neural networks (ANN), fuzzy logic and evolutionary algorithm like genetic algorithm and differential evolution and each methodology has some advantages and disadvantages. [4]
A new model proposed which combines the genetic algorithm and neuro-fuzzy system with quantum computing and showed the power of using the quantum genetic algorithm to optimize ANFIS model parameter by maintaining a better performance and more accurate results [5]. The proposed model in this research improves the prediction accuracy by Double Chains Quantum Differential Evolution algorithm (DCQDE), using QDE to optimize the value of radii used in subtractive clustering fuzzy inference system which is trained by Neural Network in ANFIS Model.According to the concept above, this paper introduces a new method to predict the gold prices in Forex market. An adaptive network was used in this paper to optimize the fuzzy inference system parameters to overcome constraints of statistical methods. Finally, the proposed model improves prediction accuracy using QDE in the optimization process for radii value used in a subtractive clustering method which used in fuzzy inference systems. The evaluation results showed that building a considerate optimization model lets the performance of the proposed model is better than the comparable model.This paper is ordered as follows: Section II describes the Sugeno type fuzzy rule based system used in the proposed model. Section III defines the fuzzy subtractive clustering. Section IV demonstrate the ANFIS structure. Section V explains the differential evolution Algorithm. Section VI specify the concepts of quantum differential evolution algorithm. The detailed demonstration about the proposed model and evaluation setup and the corresponding anatomy are shown in section VII, and finally the concluding remarks are mentioned in section VIII.

2. Background and Related work

2.1 Takagi Sugeno Type fuzzy rule based system

TSK fuzzy model based on rules where the antecedent was composed of linguistic variables and the consequent was represented by a function of the input variables. The most famous form of these kinds of rules is the one shown in the following, in which the antecedent variables formalized in a linear combination produces the consequent parameters: [6].

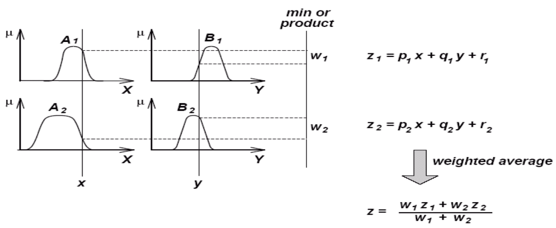

Figure 1: Sugeno type Fuzzy System

2.2 The fuzzy subtractive clustering

When the number of clusters is unknown for a given set of data, [7] said Subtractive clustering, is a fast, one-pass algorithm for estimating the number of clusters and the cluster centers in a set of data and can be used to initialize iterative optimization-based clustering methods (Fuzzy C-Mean) and model identification methods (like ANFIS).

2.3 ANFIS Structure

Neural networks and fuzzy logic are two complementary techniques in building intelligent systems [8]. While neural networks are a computational structure that perform well when dealing with raw data, fuzzy logic deals with logic using linguistic information which is given from system analyst [9]. Fuzzy systems can't learn and can't adapt themselves to new climate. On the other hand, although neural networks can learn but they are inconspicuous to the user [10].A Neuro-fuzzy system is a neural network which works like a fuzzy inference model. It can be trained to develop the fuzzy rules and determine membership functions for input and output variables of the system, also expert knowledge can be added to the structure of the Neuro-fuzzy system [11].ANFIS is a type of adaptive networks that works like fuzzy inference systems. The main structure of ANFIS model consists of 5 layers as shown in Figure 2 [12].

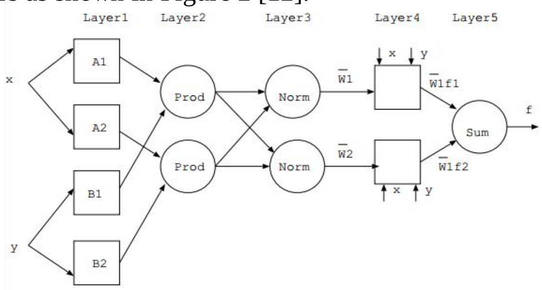

Figure 2: ANFIS Layers

2.4 Differential Evolution

Differential Evolution (DE) algorithm is a method that optimizes a problem to minimize an objective function which can realize the objectives of the problem without any change in the constraints. The DE algorithm is like genetic algorithms, a population based algorithm using the similar operators; mutation, crossover and selection. The main disparity in finding better solutions is that genetic algorithms depend on crossover while DE based on mutation operation. This process is based on the differences between pairs of solutions in the population that was chosen randomly. [13]It has three main advantages: return the best global minimum with no matter about the initial generated values, fast convergence and utilizing a few control elements. [14]The other important advantages are simplicity, speed, easy usage, very readily adjustable for discrete and integer optimization, more efficient in nonlinear constrained optimization and beneficial in optimize intermodal search spaces. [13]The algorithm uses mutation operator as a search technique and selection operator to push the search toward the potential areas in the search space [15]. The DE algorithm employs an irregular crossover which can pick child carries attributes from one parent often than it does for others, by employing the components of the existing population members to build trial population, the recombination (crossover) operator efficiently tousle information about successful combinations, pushing the search for a better solution space. [16]

2.5 Quantum Differential Evolution Algorithm

QDEA uses superposition of many states known as Q-bit for the representation of individuals and updates the individuals depending on their values with respect to the global best solution by suitably control the mutation and crossover parameters and the operators acting directly on the superposition states of the individual. [17]

2.5.1 Qubit Encode

The smallest information unit in quantum computing stored in two-state quantum computer is named a quantum bit (Qubit). The state of quantum bit may be in a (0) state, a (1) state or any superposition of the two state and can be represented as

$$|\psi\rangle = \alpha|0\rangle + \beta|1\rangle$$

The system will give "0" state when the whole probability is $|\alpha|^2$ and will give "1" state when the whole probability is $|\beta|^2$, as illustrated in [17] normalization condition must be satisfied such that

$$|\alpha|^2 + |\beta|^2 = 1$$

3. METHODOLOGY OF THE PROPOSED MODEL

Proposed model used to find the best solution for radii value of the genfis2 function works in the training phase for stock price data using ANFIS model in Matlab with double chain quantum differential evolution algorithm.

A double chains quantum differential evolution algorithm (DCQDEA) based on the amplitudes of probability for quantum bits. In this method, the probability amplitudes of each qubit are represented as two genes, each chromosome contains two gene chains, and each of gene chains represents an optimization solution. The number of genes is determined by the number of optimization parameters. Taking each qubit in the optimal chromosome as the goal, individuals are updated by applying crossover operation, and mutation on quantum angle by differential evolution to increase the diversity of population [18].Akbar and Werya (2010) showed that the stock prices might affected by many factors and a lot of papers have addressed the selection of input to mapping with financial stocks and indexes. The stock price variation in each day was selected to deal with the proposed model, it addresses the open price as input 1, highest price as input 2, lowest price as input 3 and close price as output. Performance evaluation of the proposed model was done using performance measurements. These measurements are widely used to estimate the gap between original output and predicted output produced by the proposed model. the proposed model was evaluated using MSE in the experiment.

$$MSE = (1/N) * ?\ error^2 \qquad (4)$$

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The main steps and the conceptual design are illustrated in Algorithm 1 and Figure 3.

Algorithm 1: Proposed methodology

Step 1: Data Pre-processing (Phase one)

Step 2: Generate initial random population

Step 3: Calculate Radii value

Step 4: Initialize Anfis model

Step 5: Perform optimization algorithm using DCQDEA (Phase two)

Step 6: Find best performance and accuracy.

Step 7: Stop

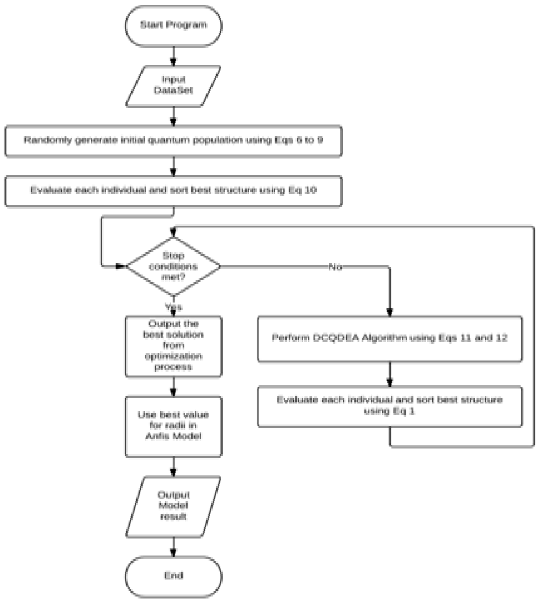

Figure 3: Flow Chart of the proposed model

4. IMPLEMENTATION

Two major phases constituting the implementation methodology of the proposed model.

4.1 Phase one: Data Pre-processing:

Pre-processing is a process that turns the raw inputs and outputs into an understandable or acceptable form before the training process. Often, this is used to reduce the dimensionality of the input data and to optimise the generalization performance [20]. The stock price is quite different in value and may affect the performance of the prediction algorithm. So the original data is normalized by min-max method as in (5)

$$Y(i) = \frac{y(i) - g}{G - g}$$

(5)*for the time series data y, g=min{y}, G=max(y). In the experiment, four kinds of time series, e.g. the open price, close price, highest price and lowest price are normalized independently [4].*

4.2 Phase two: Optimization algorithm

The double chain quantum differential evolution algorithm is the algorithm used in the optimization phase.

1- Generate initial angle to make double chains from it

$$P_{t,1}=(\cos(L_{t,1}),\cos(L_{t,2}),\ldots,\cos(L_{t,k})) \qquad (6)$$

$$P_{t,2}=(\sin(L_{t,1}),\sin(L_{t,2}),\ldots,\sin(L_{t,k})) \qquad (7)$$

where $L_{t,k}$ is a random number between 0 and 2π, $P_{t,1}$ named cosine solution and $P_{t,2}$ named sine solution.

2- Transform to solution space

$$Q_{(t,r)c} = 0.5 * [b_t (1+\alpha_{t,r}) + a_t (1-\alpha_{t,r})] \qquad (8)$$

$$Q_{(t,r)s} = 0.5 * [b_t (1+\beta_{t,r}) + a_t (1-\beta_{t,r})] \qquad (9)$$

where t= 1: v, r = 1: k, v the number of qubits and k the population size.

3- Calculate value of objective function which equal to

$$1/_{1+MSE} \qquad (10)$$

4- Sort the best structure.

5- Mutate quantum angles, mutant L_k

$$(11)\ mutant\ L_k = L_{z1} + H.(L_{z2} - L_{z3})$$

where z1, z2, z3 and k are mutually distinct and H is the mutation control parameter which is random number generated in every generation. [21]

6- Apply crossover operation according to

$$CR\,L_{k,t} = \begin{cases} mutant\ L_{k,t} & if\ rand_k(0,1) \le CR \\ L_{k,t} & if\ rand_k(0,1) > CR \end{cases} \qquad (12)$$

where $CR\,L_{k,t}$ is the angle after crossover operation, $L_{k,t}$ is the original angle before mutation and $CR = 0.5$ is the control parameter which is found to be the best value experimentally. [18]

Table 1: Results of 20 times running

No	RMSE	PER	MTE	Radii
1	0.0379	0.0629	0.15	0.5857
2	0.0382	0.0813	0.15	0.9072
3	0.0378	0.0835	0.1	0.3398
4	0.0382	0.0652	0.15	0.499
5	0.038	0.0627	0.15	0.546
6	0.0378	0.0826	0.1	0.3373
7	0.038	0.0844	0.15	0.9931
8	0.039	0.0674	0.15	0.4913
9	0.0381	0.0847	0.15	0.9617
10	0.0378	0.0679	0.15	0.4757
11	0.039	0.0843	0.15	0.9988
12	0.0379	0.0639	0.15	0.6012
13	0.0379	0.0647	0.15	0.7186
14	0.0382	0.0674	0.15	0.4912
15	0.0379	0.0844	0.15	0.992
16	0.0378	0.0628	0.15	0.5223
17	0.0379	0.0845	0.15	0.9879
18	0.0379	0.0723	0.15	0.3786
19	0.0378	0.0825	0.1	0.3373
20	0.0378	0.0844	0.15	0.9903

The procedures mentioned above was used to determine the best value for the optimization parameter using double chain quantum differential evolution algorithm and calculate objective function according to ANFIS model using subtractive clustering to generate initial FIS for ANFIS system.

5. RESULTS AND DISCUSSION

A set of stock market data collected for the gold price from Forex market for a period from 17th September 2010 to 21th January 2011 which contains the open price, highest price, lowest price and close price for each working day [22]. To show the performance of the proposed model, testing was done on the gold price and compare its result with compared model result in [22], obtained result of the proposed model as shown in Figure 4.

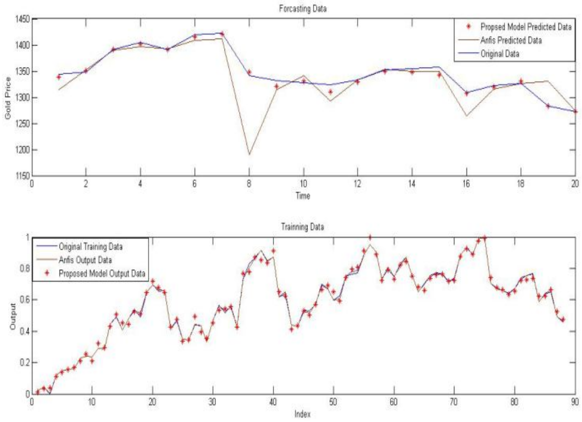

Figure 4: The proposed model result

The first part in Figure 4 illustrate the testing of the proposed model in red marks compared with the original data in blue line and Anfis model result in brown line, the second part represent the original training data in blue line, Anfis training data in brown line and proposed model output data in red marks. After running the proposed model for 20 times the averages of RMSE, MTE and Per were calculated and illustrated in Table 1.The compared model [22] presents a comparison of Artificial Neural Network (ANN) and Adaptive Neural Fuzzy Inference System (ANFIS) for predicting a real system, gold price. Also, it compared a new hybrid model which is a weighted average of the ANN and ANFIS model. it used two prediction machine models in ANN, a model which feeds back the network output as input and another model that does not do it. it evaluate the methods using three performance measurements Root Mean Squared Error (RMSE), percentage error and Mean Tendency Error (MTE). At last, a Wavelet denoising algorithm is applied to the data, but due to the chaotic structure of the gold price, it impairs data and causes to reduce the performance of prediction result. The gold prices collected using Meta Trader software which is a platform for gathering Forex market data. Data collected is same as data used in the proposed model and the same period chosen.

The results in Table 2 show that the proposed model is better than all comparable models.

Table 2: Comparison between the Proposed model and Comparable models

Model		Prediction Performance Measurement		
		RMSE	Per	MTE
Proposed Model		0.038045	0.07469	0.1425
Comparable Models	ANN	2.62	0.14	0.49
	ANFIS	2.52	0.13	0.46
	Hybrid model	2.54	0.13	0.47
	ANN (denoised)	2.47	0.13	0.18
	ANFIS (denoised)	2.77	0.15	0.3
	Hybrid (denoised)	2.72	0.15	0.3

6. CONCLUSION

Many soft computing approaches have successfully applied in the prediction of stock market price and showed good performance. In this study, the main object of this paper is to investigate the power of QDEA by using it to optimize the radii value used in subtractive clustering method applied to initialize fuzzy inference systems and use it in Neuro-fuzzy model "ANFIS" to train the system by historical data of gold price and predict the gold price in the Forex market. The proposed model was implemented and evaluated using gold price in the Forex market and compared with ANN and ANFIS models. The obtained result showed the performance of the proposed model is better than the comparable models. The soft computing techniques employed in this paper are the ANFIS model and the double chain quantum differential evolution algorithm model.

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