Prediction of Artificial Neural Network Hybrid with Chaotic Genetic Algorithm / Iraqi Oil as a Model

التنبؤ بالشبكة العصبية الاصطناعية المهجنة بالخوارزمية الجينية الفوضوية / النفط العراقي انموذجا

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Abstract:

Forecasting is one of the scientific and modern developed methods used in planning and decision-making processes. In this study, a new unconventional method was used to forecast oil in Iraq using the artificial neural network method and hybridizing it with the chaotic genetic algorithm to forecast Iraqi oil production and prices. using more than one method in forecasting leads to increasing the accuracy of future estimates, as two models were combined: the artificial neural network and the chaotic genetic algorithm (CGANN). The study concluded that the hybrid model (CGANN) leads to a significant improvement in the accuracy of the model, overcoming the weaknesses between the two models, combining the strengths of both, and providing a more accurate forecast of Iraqi oil until the year 2035.

المستخلص :

يعد التنبؤ أحد الطرائق العلمية والحديثة المطورة المستخدمة في عمليات التخطيط واتخاذ القرار ، حيث تم في هذه الدراسة استخدام أسلوب جديد غير تقليدي للتنبؤ بالنفط في العراق باستخدام اسلوب الشبكة العصبية الاصطناعية وتهجينه مع الخوارزمية الجينية الفوضوية للتنبؤ بإنتاج وأسعار النفط العراقي. إذ ان استخدام أكثر من طريقة في التنبؤ يؤدي إلى زيادة دقة التقديرات المستقبلية، حيث تم الجمع بين أنموذجين هما الشبكة العصبية الاصطناعية والخوارزمية الجينية الفوضوية (CGANN)، توصلت الدراسة إلى ان النموذج المهجن (CGANN) يؤدي إلى تحسين دقة النموذج بشكل كبير والتغلب على نقاط الضعف بين النموذجين وجمع نقاط القوة لكليهما وإعطاء التنبؤ بالنفط العراقي حتى عام 2035 بشكل ادق.

Introduction

Iraq is one of the founding countries of the Organization of the Petroleum Exporting Countries and depends mainly on oil, as oil is considered one of the most important sources of the main and basic forms of energy for building modern life due to its important role in the process of prosperity and economic development as a result of the expansion of its applications in all sectors as it is the main source of income. The aim of the study is to shed light on some modern, developed and unconventional statistical methods by applying a model for forecasting Iraqi oil, which is a hybridization of the chaotic genetic algorithm (CGA) with an artificial neural network (ANN) to solve various optimization problems, as artificial neural networks are one of the important methods. In the field of statistics, through its ability to train, learn, and predict, and it is considered a mathematical model for modeling non-linear statistical data, the relationship between statistics and artificial neural networks has received increasing attention in recent years from researchers and workers in the field of statistics. Both fields. We find that many of the ideas that researchers have in neural networks are based on the basics of statistics, and many of the statistical methods and means can be programmed by employing a network and building an algorithm for it, and the flexibility of artificial neural networks as an alternative to traditional statistical methods. Using more than one method leads to increasing the accuracy of future estimates. Using the language program (R.4.2.2), two models were combined, namely the artificial neural network and the chaotic genetic algorithm (CGANN), to obtain more accurate prediction results and reduce prediction errors, as well as hybridization. The two models combine the strengths of the two techniques, as the stability of the artificial neural network depends on using the results of the chaotic genetic algorithm as one of the inputs to the artificial neural network. The real data for the period (1976-2022) were studied, and the results showed that the hybrid method (CGANN) obtained the lowest values (MSE, MAPE) among the three methods; thus, this method confirmed its ability to improve the accuracy of prediction by taking advantage of the strengths of each

method by combining the two methods together, indicating that the hybrid method (CGANN) provides the best performance in predicting oil exports until 2035.[7]

Reference review: There are many studies that have been monitored that are directly related to the current study, and they will be listed as follows:

▪ The study (Haidar et al, 2008) used a synthetic study to predict crude oil prices for neural networks in the short term based on a three-layer neural network. The study also concentrated on determining the optimal network structure by testing a variety of features as inputs. The results demonstrated that the neural network method is capable of achieving highly accurate predictions. [12]

▪ The study (Mushtaq, 2021) concluded the possibility of building a model for artificial neural networks for the purpose of predicting the Iraq Stock Exchange index. This model is represented by the feed-forward network and using the (Trainlm) function, one of the functions of the backpropagation algorithm for error. The study concluded by adopting the artificial neural network system as a method for predicting the Iraq Stock Exchange index by investors, brokers and financial analysts in the Iraq Stock Exchange. [2]

▪ The study (Hoda and Sahera, 2024) aimed to develop a model for predicting electrical load by applying General Vector Regression combined with the Chaotic Genetic Algorithm to enhance prediction performance. The Chaotic Genetic Algorithm addresses the challenge of optimizing support vector regression parameters. Thus, the support vector regression model was integrated with the Chaotic Genetic Algorithm to identify the optimal parameters for improving the regression model's performance, enhancing its accuracy and efficiency in prediction tasks. This hybrid model was tested for predicting electricity consumption in the southern region of Iraq for the period 2020-2029. The results indicated that this hybrid model, incorporating the Chaotic Genetic Algorithm, outperformed other prediction models in terms of accuracy and efficiency based on statistical prediction accuracy criteria. [14]

▪ The study (Habibeche et al, 2020) focused on utilizing artificial neural networks combined with the chaotic genetic algorithm to

estimate the parameters of chaotic time series and predict their future behavior. The results revealed that varying the number of samples and parameters influenced the prediction accuracy. It was found that the artificial neural network method, when combined with the chaotic genetic algorithm, proved to be the most effective for predicting chaotic time series. The simulation results further demonstrated that this method is effective for future applications and that artificial neural networks are well-suited for predicting chaotic systems. [15]

Artificial Neural Network [4][7]

An artificial neural network (ANN) is defined as a network of interconnected virtual nodes created through computer programs to mimic the functioning of biological neurons found in human brains. This network uses mathematical models to process information. Both biological and artificial neural networks consist of basic processing units that carry out specific, straightforward tasks. However, the overall performance of the network is largely determined by the strength and pattern of the connections between these neurons, as these connections dictate how information is processed and transmitted across the network. The artificial neural network processes information in parallel using units known as nodes or neurons. Its capacity to learn and model both linear and non-linear relationships enhances its effectiveness in handling complex data. One of the primary functions of artificial neural networks is to emulate how the human brain processes and analyzes information. By learning, differentiating, recognizing, and utilizing these features, the network builds a mathematical model that can analyze data and predict outcomes. Neural networks are able to model nonlinear relationships by using nonlinear activation functions.

The mathematical formula for the artificial neural network is as follows: [5]

$$net_j = \sum_{i=1}^{n} w_{ij}x_i + b_j = w_{j1}x_1 + w_{j2}x_2 + w_{j3}x_3 + \cdots + w_{jn}x_3 + b_j \quad \dots (1)$$

whereas:

W_{ij}: Represents weight.

x_i: Represents input value.

b_j: Represents bias value.

Artificial neural network components

Most artificial neural network models consist of three or more basic layers, according to the following:

1. Input layer: This is the first layer that receives the data to be processed by the network. It serves as the entry point for the information that the model will work with. [3]
2. Hidden layer: It represents the second layer that processes and analyzes data progressively. The outputs from one layer are passed as inputs to the next layer through the network connections, enabling continuous processing and analysis until the data reaches the final layer. [11]
3. Output layer: It represents the last layer that produces the ultimate output based on the operations and processing carried out on the inputs from the first layer [17]
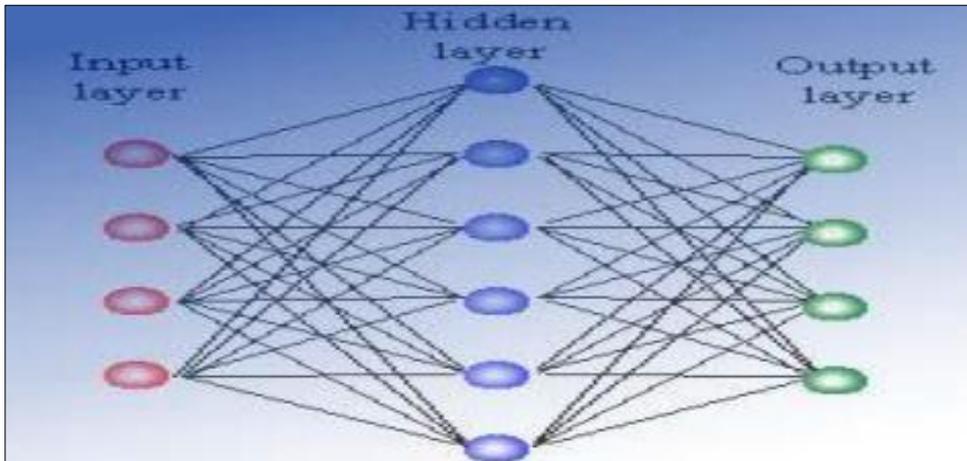
As illustrated in Figure (1):

Figure (1): Shows the components of the artificial neural network. [6]

Types of artificial neural network [8]

Artificial neural networks can be classified into several types, the most important of which are the following:

1.   **Feedforward neural network:** Sends data from input units to output units by processing data that spans multiple layers of units without feedback connections.
2.   **Feedback Neural Network:** These networks include feedback connections that extend from the output units back to the input units within the same layer.

Artificial neural network architecture [5]

The structure of an artificial neural network is shaped by three key factors: the number of layers, the number of processing elements (or neurons) within each layer, and the manner in which these elements are interconnected. These factors collectively influence the network's ability to process and analyze data. When counting the layers in the network, the input layer is not included.

Artificial neural networks can be classified into two types in terms of layers, as follows:

1. **Single-layer networks:** This type of artificial neural network is one of the simplest and oldest models, specifically designed to handle linear problems. It does not include a hidden layer and consists solely of a single layer of weighted connections. The network is characterized by an input layer that receives signals from the external environment, which are then passed forward to the output layer. The output layer processes these signals, producing the network's response and establishing direct relationships between the inputs and outputs.

2. **Multi-layer networks:** This type of network includes one hidden layer and may have one or more additional layers, enhancing its ability to process data. It is particularly notable for its capability to find optimal solutions to complex problems.

Education in artificial neural network [13]

The artificial neural network accomplishes its functions by learning by adjusting the weights in order to achieve homogeneity between the inputs and the outputs. Learning methods can be divided according to the following:

1. **Supervised learning:** The idea of teaching by a teacher is based on displaying training data on the network, examining each set of inputs corresponding to a set of outputs. The neural network compares its actual outputs with the desired outputs, calculates the error based on the difference between them, and then adjusts the weights to minimize this error and reduce the discrepancy. The output shape and the target shape using the weight updating function.

2. **Unsupervised learning:** The unsupervised learning method enables the network to generate outputs independently without prior knowledge. This approach leverages the network's ability to discover and internalize distinctive features of the presented inputs, creating an internal representation without needing examples of desired outputs or pre-defined instructions.

3. **Reinforcement learning:** Reinforcement learning integrates elements of both supervised and unsupervised learning methods. Unlike supervised learning, where the network is given actual output values, or unsupervised learning, where it operates without feedback on its outputs, reinforcement learning involves the network receiving feedback on the correctness of its actions or strategies. This feedback helps the network learn and improve its performance based on the success or failure of its decisions rather than explicit output values.

chaotic genetic algorithm [9][1]

The Genetic Algorithm (GA) is a versatile and effective tool for solving optimization problems. However, it faces two primary challenges: slow convergence and the tendency to settle at local optima. To address the issue of local convergence, which is often due to decreased population diversity, the chaotic sequence is integrated with the GA. This combination aims to enhance the algorithm's performance by improving exploration and preventing premature convergence to suboptimal solutions.

The Chaotic Genetic Algorithm (CGA) is designed to tackle non-linear and complex optimization problems. Its fundamental approach involves transforming the problem variables from the solution space into the chaotic space. In other words, the Chaotic Genetic Algorithm can expand the search sample space due to the power of the chaotic algorithm, and it can be found on the global optimal

solution local optimization problems can be avoided because of the initial sensitivity of the chaotic optimization algorithm. Then, the solution search is conducted using three properties: randomness, efficiency, and chaotic variables. Therefore, the chaotic genetic algorithm is one of the best candidates for solving optimization problems.

Using hybrid artificial neural network with chaotic genetic algorithm [10][16]

The current study adopted the hybrid model method (CGANN) to enhance predictive performance and improve the artificial neural network approach. The Chaotic Genetic Algorithm (CGA), when combined with the back-propagation neural network model, forms a widely adopted hybrid model. The genetic algorithm, which mimics natural evolutionary principles, is particularly useful for solving highly complex, nonlinear problems that are difficult for conventional methods to address. Incorporating the chaotic genetic algorithm to fine-tune the neural network's weights proves effective in enhancing prediction accuracy. By using the genetic algorithm to optimize these weights and the network gets rid of rough weights. the model's structure becomes more streamlined, leading to more stable and reliable predictive outcomes. This optimization of weights contributes to the improved efficiency of the artificial neural network (ANN) within the hybrid (ANN-CGA) model. (CGA) concepts are used to improve the weights, which leads to reducing error. Between the actual and expected outputs of artificial neural networks.

Result Discussion

A set of real Iraqi oil data for the period (1976-2022) * was used using the (R.4.2.2) program. To find three main objectives, the first is to design and build the artificial neural network (ANN) model, the second includes building the chaotic genetic algorithm (CGA), and the third objective is to design and build a hybrid model that combines the chaotic genetic algorithm and the artificial neural network (GCANN) and compare these models to obtain the best model to use in the process of forecasting Iraqi oil exports. The study data was converted into standardized data to remove the difference in units, and the data was divided into two parts: 80% training data and 20% test data.

The results of the chaotic genetic algorithm (CGA) were entered as one of the inputs of the artificial neural network (ANN) with the basic inputs (oil prices and production). A hybrid model (CGANN) is obtained to get rid of the rough weights determined by the backpropagation algorithm, and to obtain the optimal weights, then the process is repeated (1000) times with a learning rate (0.001) and with weights close to zero first to start the network training process and second to ensure that values exactly equal to zero are not obtained, which prevents the training process from being carried out. Table (1) shows the optimal weights that were obtained.

Table (1)

Values of weights of the hybrid artificial neural network (CGANN).

		Hidden Layer 1		Hidden Layer 2		Output Layer
		Node1	Node2	Node1	Node2	
Input Layer	(Bias)	0.02843856	5.3908012-			
	X1	0.06850836	4.6718249			

	X2	1.14786824	0.9829775-			
	X3	1.80113000	1.6465850-			
Hidden Layer 1	(Bias)			0.9452422	9.796281-	
	Node1			2.5205584-	64.616871	
	Node2			31.7015120-	159.762644	
Hidden Layer 2	(Bias)					0.245790-
	Node1					2.423318-
	Node2					1.202491

The architecture of the hybrid network can be illustrated as shown in Figure (2).
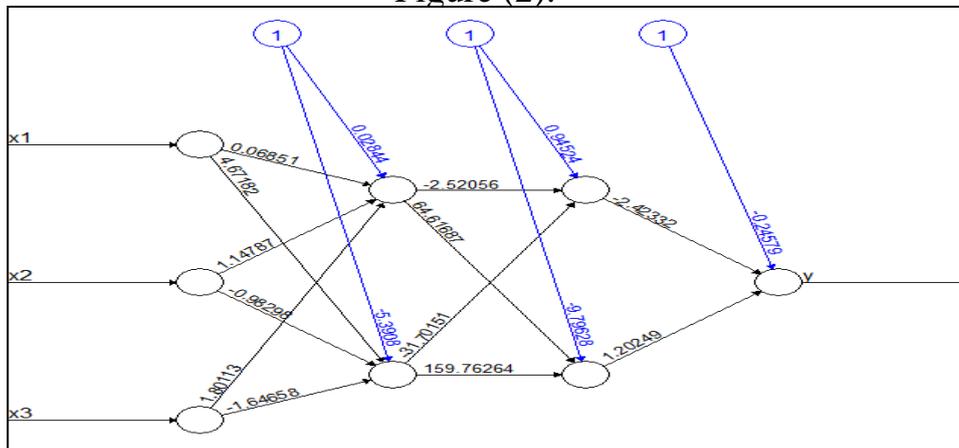
Figure (2) Hybrid Convolutional Neural Network (CGANN) architecture.

We notice from Figure (2) the architecture of the hybrid network (CGANN) where the algorithm outputs are entered as inputs with prices and production to obtain more accurate results, as the hybrid architecture consists of two hidden layers and one output layer, and the value reached (MSE = 0.1769044), (MAPE = 0.605032).

Estimated values of sample data

The estimated values for each of the three methods (artificial neural network, chaotic genetic algorithm, hybrid method) were

extracted and the data were organized and displayed in a way that shows the performance of each method. Table (2) includes the actual values and estimated values for each method.

Table (2)

Internal estimated values for each method.

Estimated export values CGANN	Estimated export values ANN	Estimated export values CGA	Real export values	Year
2.135804	2.143942	1.621775	2.275	1976
2.150553	2.157832	1.639829	2.293	1977
2.182538	2.17317	1.88755	2.752	1978
2.182538	2.17317	2.249006	3.247	1979
2.166454	2.172418	1.814918	2.415	1980
0.888635	0.680036	0.973736	0.872	1981
0.794964	0.647761	0.982391	0.846	1982
0.61642	0.572262	0.966586	0.702	1983
0.945019	0.783323	1.056337	0.867	1984
1.143287	1.159778	1.232133	1.120	1985
1.14066	1.052966	1.305704	1.376	1986
1.797514	1.798861	1.547387	1.760	1987
2.182267	2.17316	1.760191	2.197	1988
2.182538	2.17317	1.904248	2.413	1989
1.678629	1.709648	1.537055	1.694	1990
0.003277	-0.1727	0.651413	0.039	1991

0.078182	0.216717	0.922935	0.060	**1992**
0.050425	0.12485	0.897644	0.059	**1993**
0.048804	0.122988	0.904557	0.060	**1994**
0.065364	0.185419	0.923425	0.064	**1995**
0.169694	0.38288	0.97786	0.092	**1996**
0.808596	0.792011	1.153446	0.717	**1997**
1.632737	1.566242	1.480292	1.568	**1998**
2.162557	2.168418	1.687313	2.080	**1999**
2.159305	2.170228	1.748096	2.057	**2000**
2.16457	2.170642	1.727145	2.016	**2001**
1.680636	1.720754	1.545829	1.621	**2002**
1.114235	1.079511	1.182279	1.000	**2003**
1.457195	1.574519	1.463368	1.500	**2004**
1.545624	1.628121	1.454903	1.400	**2005**
1.680865	1.683617	1.53724	1.500	**2006**
1.626282	1.651137	1.35475	1.640	**2007**
1.853731	1.741563	1.783605	1.855	**2008**
1.831313	1.794579	1.710129	1.906	**2009**
1.856206	1.776901	1.769867	1.890	**2010**
1.92425	1.944034	2.034919	1.900	**2011**
1.789085	1.701175	1.248424	1.991	**2012**
1.790388	1.701761	1.252106	1.921	**2013**
1.706096	1.667243	1.194504	0.951	**2014**

1.249108	1.334811	1.162742	1.229	**2015**
1.280151	1.416735	1.309455	1.392	**2016**
1.412972	1.53932	1.31264	1.387	**2017**
1.583503	1.634754	1.356906	1.654	**2018**
1.631199	1.655872	1.388141	1.876	**2019**
1.649303	1.663426	1.403828	1.987	**2020**
2.182538	2.17317	2.642604	1.102	**2021**
2.182538	2.17317	2.890791	1.209	**2022**

Source: From the results of the program (R.4.2.2).

Table (3) Expected values for predicting Iraqi oil (2023-2035).

Table (3)

Future forecast values for Iraqi oil exports (2023-2035)

years	Prediction values of Iraqi oil exports using the hybridization method (CGANN)
2023	2.182538
2024	1.985009
2025	1.77294
2026	1.727216
2027	1.721047
2028	1.733528
2029	1.748473
2030	1.760701
2031	1.787991

2032	1.891482
2033	1.988894
2034	1.947995
2035	1.842783

Source: From the results of the program (R.4.2.2).

We notice from the values that there is an increase and decrease in the values of future predictions, and this indicates that Iraqi oil exports will increase or decrease in the future according to the increase or decrease in production and prices, and this is consistent with economic theory.

Conclusions:

The artificial neural network was used with the chaotic genetic algorithm and the results were shown as follows:

1. Chaotic Genetic Algorithm (CGA) is an excellent tool and efficient method for solving nonlinear and complex optimization problems.

2. Hybridizing the artificial neural network (ANN) with the chaotic genetic algorithm (CGA) makes the hybrid CGANN model more accurate and more efficient for predicting Iraqi oil.

3. The hybrid model (CGANN) leads to a significant improvement in the accuracy of the model, overcoming the weaknesses between the two models, combining the strengths of both, and providing a more accurate forecast of Iraqi oil until 2035.

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