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“Developing a Neural Network Model for Predicting Stock Market: The Case of the Saudi Market”

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Abstract— Obtaining accurate information for maximizing the profits from stock market investments is complex due to several factors, one of them being the price of stocks during recent years. Artificial Neural Networks (ANNs) are widely used in the aspect of prediction for decision-making. In the case of the Stock market in Saudi Arabia, there is a lack of tools and research related to predicting Stock market activity using Radial Basis Function Neural Networks (RBFNNs). The aim of this project is to provide stock market investors with a viable system to help them find promising opportunities for success in the Saudi Market exchange. The adopted method is based on the RBFNN as it is effective in small to medium datasets; moreover, it can also be used for large non-linear datasets. Performance is further improved through optimizing the hyperparameters within the RBFNN. Accordingly, our results showed that the RBFNN algorithm predicts activity of the Saudi stock market better than ANN algorithm and linear regression. So, the value of RMSE was predicted. At 84% the MSE value was predicted at 71%, and the MAE value was predicted at 58%, RBFNN proved to be equally effective on the real data set, producing better results compared with ANN and linear regression, where the RMSE was chosen for comparison between models.

Keywords—Predicting, Stock markets, Neural Network, Radial Basis Function Neural Network, Saudi Arabia

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الملخص:

إن الحصول على معلومات دقيقة لتعظيم أرباح استثمارات البورصة أمر معقد بسبب عدة عوامل، أحدها سعر الأسهم خلال السنوات الأخيرة. تستخدم الشبكات العصبية الاصطناعية (ANN) على نطاق واسع في جانب التنبؤ لاتخاذ القرار. في حالة سوق الأسهم في المملكة العربية السعودية، هناك نقص في الأدوات والأبحاث المتعلقة بالتنبؤ بنشاط سوق الأسهم باستخدام الشبكات العصبية ذات الوظيفة الشعاعية(RBFNNs) . الهدف من هذا المشروع هو تزويد المستثمرين في سوق الأسهم بنظام قابل للتطبيق لمساعدتهم على إيجاد فرص واعدة للنجاح في سوق الأسهم السعودية. تعتمد الطريقة المعتمدة على RBFNNلأنها فعالة في مجموعات البيانات الصغيرة إلى المتوسطة؛ علاوة على ذلك، يمكن استخدامه أيضًا لمجموعات البيانات غير الخطية الكبيرة. تم تحسين الأداء بشكل أكبر من خلال تحسين المعلمات الفائقة داخل RBFNN. وبناءً عليه ، أظهرت نتائجنا أن خوارزمية RBFNN تتنبأ بنشاط سوق الأسهم السعودية بشكل أفضل من خوارزمية ANN والانحدار الخطي .لذلك، تم توقع قيمة *RMSE*. عند 84 ٪، تم توقع قيمة MSE عند 71 ٪، وتم توقع قيمة MAE عند 58 ٪، أثبتت RBFNN أنها فعالة بنفس القدر على مجموعة البيانات الحقيقية، مما أدى إلى نتائج أفضل مقارنة مع ANN والانحدار الخطي، حيث تم اختيار RMSE من أجل مقارنة بين النماذج.

الكلمات المفتاحية: التنبؤ، أسواق الأسهم، الشبكة العصبية، الشبكة العصبية للوظيفة الشعاعية، المملكة العربية السعودية.

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Introduction

The stock exchange in Saudi Arabia is a cornerstone for the county's economy and a major player in the Middle East and around the world. Therefore, accurate predictions for the activity of share prices can help investors profit from trading in this important sector. A predictive model with the proper performance assessment strategy can be considered the main component in an intelligent recommendation system. The proposed methodology is based on a technique that has proven to be useful in similar datasets; it showed improved performance metrics compared to other comparable machine learning techniques. Saudi Arabia's financial system has grown in recent years, becoming stronger and more efficient. The quality of services provided by financial institutions has improved significantly as part of Vision 2030's financial developments, and the Saudi market's capabilities contribute significantly to economic growth. Previous research has indicated that the capital market performs well in terms of volume and liquidity, and as a result, the Saudi stock market is regarded as one of the major financial markets in the developed world. Furthermore, Saudi Arabia's economy is heavily reliant on oil as a significant source of revenue, and its stock market is predicted to be volatile when oil prices fluctuate. Saudi Arabia is a member of the Group of Twenty (G20), an international economic cooperation group comprised of leaders from 19 countries. Together, the G20 members represent about 80% of the global economy, two-thirds of the world's population, and three-quarters of global trade. Moreover, Saudi Arabia is currently compiling a package of economic reforms and business outside the country. Finally, the Saudi stock market suffers from severe fluctuations during different periods due to its exposure to external crises such as the COVID-19 pandemic: if a pandemic or a similar crisis were to cause the economy to decline, economists would need to rein in excessive marketplace volatility to ensure financial and macroeconomic stability [1-3].

The Saudi stock market is one of the largest financial markets among similar markets in developed countries. Oil is the main source of the Saudi economy, and the fluctuations of the stock market are likely to be based on fluctuations in oil prices [4]. Each stock market is comprised of the investors who own shares in companies traded in that marketplace. The value of share prices reflects the company's performance, rising when the company is doing well. Stocks also rises when the economy is high [5]. Saudi Arabia is also a de facto member of the Organization of Petroleum Exporting Countries, playing an important role in the oil market by managing its ownership of billions of barrels of oil. However, in 2016, Saudi Arabia took measures to reduce its dependence on oil as a major economic contributor, developing strategies to reduce its dependence and to diversify non-oil sources of income; this approached is referred to as Vision 2030 [6]. The Saudi stock market, known as the Tadawul, is an approved trading platform in Saudi Arabia for trading on the stock market. As of now, Tadawul has almost 200 organizations registered for trading. The Tadawul All Share Index is the financial exchange list that tracks of all organizations recorded on the Saudi stock exchange [1], [7].

This market began as an informal market in the fifties and continued in this way until the eighties, when the government of the Kingdom of Saudi Arabia stepped in. In 2003, the government established the Capital Market Authority (CMA), which was entrusted to develop the financial market [7]. As authority was transferred to the CMA, it became the regulator of shares in Saudi Arabia. While trading was limited to Saudis at first, trading was eventually opened to foreign investors by the Gulf Cooperation Council in 2008. In 2015, the Saudi CMA was permitted to allow foreign institutions to invest. Several measures have been taken by the CMA to allow foreign investors to own up to 49% of the shares. By the end of 2017, the NASDAQ and the Tadawul consented to an arrangement to change Tadawul's post-exchange innovation infrastructure. Now complete, it permits the Saudi bourse to present new resource classes, like subsidiaries, to the market. The connection between securities exchange improvement and financial development has been the subject of much discussion for some time. The research centered on developing business sectors; no significant review exists for business sectors in oil-based economies. To produce our results, we had to use a blend of various techniques, such as consolidating quantitative and subjective techniques. This approach ensured the legitimacy and unwavering quality of our results [1-9].

Related Work

Liang [2021] proposed a system to use AI techniques to predict the stock market, analyzing stock market data using an RBFNN because it is a new and effective neural network with a high computing speed and a high ability to generalize. Because RBFNN uses a non-linear planning function, it is very suitable for forecasting in the stock market. By comparing data processing and results between the RBFNN and the feedforward neural network, the radial network was proven to be much better. Also, it provides better predictions for stock prices when compared to 40 other prediction models [10]. Alotaibi [2018] proposed a system wherein ANNs used a backpropagation algorithm to predict the movement of the Saudi stock market. Their dataset was chosen from real data from the Saudi stock exchange (Tadawul stock market exchange). As such, the dataset included 2 futures: the average price and the closing price. The ANNs were trained and then the data was tested, proving that an ANN using a backpropagation algorithm has high capacity and accuracy levels for predicting stock market activity [5]. Vrbka [2017] found that the capacity to precisely anticipate share value advancement is critical for financial backers to realize a good return from their investments. By utilizing high accuracy anticipation frameworks, financial backers can receive incredible gains [11]. Loayza [2021] said that the considerations for this model center on the methodological analysis from the point of view of the Peruvian financial environment. Other considerations are the conceptualization of neural network architecture, backpropagation algorithms, and the analysis parametrics of neural networks

[12]. According to Padhiary [2011], stock value forecasting is a significant field of examination in finance because of the supposition that the market can be effectively anticipated. At that point, financial backers might see the greatest returns on their investments. The financial exchange or value market is a public market into which an enormous measure of capital is invested and exchanged. Numerous analysts describe the market as dynamic, non-direct, convoluted, and turbulent in nature [13]. Fallatah [2011] stated that accuracy is measured through the correlation coefficient, which measures how close the expected price values are compared to the direction of the actual price values. so that if they recorded low values in the (RMSE error) as the model will become highly predictable, as the result was 99.9% [14]. Sharma [2021] proposed that the irregular conduct of financial exchanges makes estimation difficult. Consequently, new approaches to gauging models are continually investigated, including customary measurable procedures such as the autoregressive coordinated moving average [15]. Nti [2021] suggested that a few petabytes of information are created consistently from the various sources that influence the financial exchange. A reasonable and proficient combination of these information sources (factors) provides insight to offer better pre-phrasing precision on the securities exchange [16]. Madhu [2021] explained that different AI strategies, such as Support-vector machine (SVM), have been planned and created to manage the issue of foreseeing the future pattern of choice cost [17]. In the work of Alturki [2020], the recurrent neural network RNN was used to test the weak shape of the Saudi stock market and produce to predict the next day's trading signal for many stocks in the Saudi market. The results showed that RNN achieves trading with an accuracy of 55% [18]. Olatunji [2013] mentioned that the outcomes from demonstrated that the proposed ANN model predicted the following day's shutting value financial exchange with an exceptionally low RMSE down to 1.817 [19]. UniTicker [20] provides a tool called 'Ticker Chart', which is considered as one of the best modern tools as it contains many tools for the investor to analyze stocks. In addition, Quantacula [20] provides 'Wealth-Lab Pro', which provides daily news in addition to technical analysis of Saudi stocks and companies in the financial market and integrates all the information and indicators of any stock in addition to its historical data.

Methods of Study

Artifiction Neural Network

The use of automated learning algorithms has become increasingly popular due to their ease of use and accurate results. Many algorithms have proven themselves effective, such as the neural network algorithm. Many researchers prefer to use the ANN algorithm because it provides highly accurate results. A neural network is known as an ANN or an SNN. ANN is a supervised learning algorithm that shows us basic relationships in a dataset through a model inspired by the functions of the brain's neural networks. It solves the problems that

occur in the field of AI, the field of machine learning, and the field of deep learning. ANN is a very powerful and flexible model that works well with unstructured inputs such as audio and video. ANN can achieve high performance, and networks are typically organized in layers. There are three types of neural network layers: the first layer is the input layer containing input variables, the second layer is the hidden layer containing any layer between the input and output layers, and the third layer is output layer containing generated predictions for classification or regression, as shown in Fig. 2 [21], [22]. ANN has two main phases: the feedforward phase computes values from inputs to outputs, and the backpropagation phase adjusts the weights to minimize the loss function [23-25]. There are various types of ANNs, such as RBFNN, which is considered important because it learns fast and its ideas are comparable to the theory of approximation function [26].

ANN techniques are divided into several categories: a classification neural network is trained in classifying a set of data into a specific category, prediction ANN is trained to produce expected outputs from specific inputs, clustering ANN is trained in identifying a unique feature of data and classifying it into different categories, and association ANN is trained in remembering a certain pattern [27].

Thus, the ANN algorithm has many different advantages including the ability to be used in classification and aggregation. It also has the ability to process in a balanced manner, as it completes more than one important job at a time. It also has the ability to train a machine quickly and make decisions, and stores information on the entire ANN algorithm. Therefore, if some information is lost, the loss would not affect the performance of the algorithm [28].

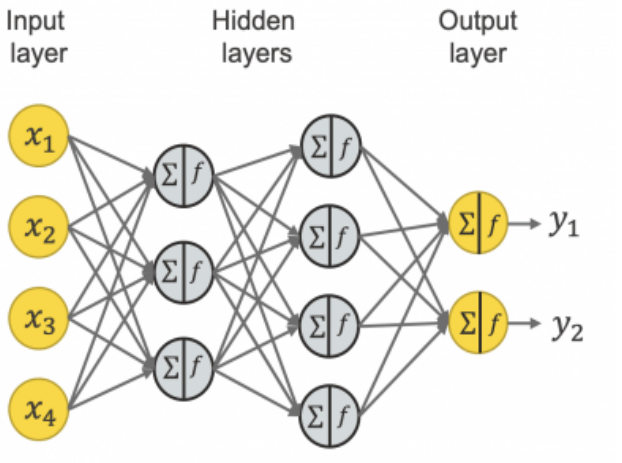

Fig. 1. **ANN architecture.[18]**

4. Radial Basis Function Neural Network

According to the principle of Bayes' theorem, RBFNN is a modern non-linear model for dealing with regression and classification that can control the distribution of inputs

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intensively when training to give an output of real value. This neural network uses the function approximation theory, through which one or more dependent variables are predicted. When structuring the model, we notice that it is very similar to the dependent division of cell neurons in neural networks consisting of three layers: input layer, hidden layer, and output layer. It is distinguished by a clear difference in the hidden layer, as it contains a Gaussian function, which has properties that enable it to predict effectively. We note an effective and distinctive difference also achieved by adjusting the weights after the hidden layer; the shift from the input space to the second layer space is non-linear, while the shift from the second layer to the output layer is linear, which speeds up the learning process and reduces inaccuracy [29], [30].

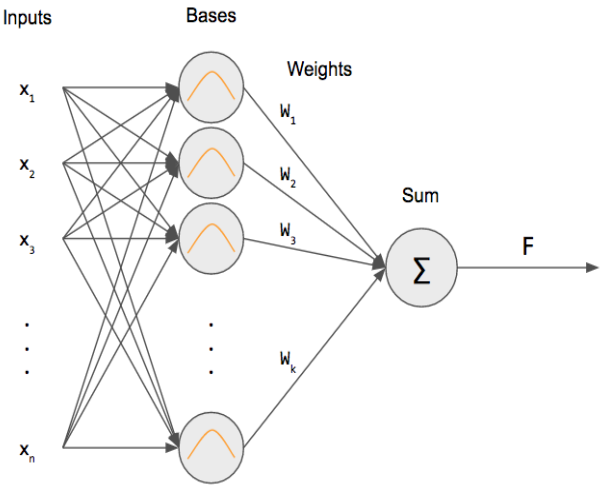

Fig. 2. **The Radial Basis Function Neural Network Architecture.[21]**

Moreover, regression or curve fitting refers to the general challenge of detecting an underlying function from a set of noisy training data using MLP networks. Exact interpolation is a specific instance in which the output function passes through all the data points perfectly [31].

To precisely interpolate a sequence of N data points in a multi-dimensional space, all the D dimensional input vectors $\mathbf{x}^p = \{x_i^p : i = 1, \dots, D\}$ must be mapped onto the target outputs t^p. The goal is to find a function f(x) [32]:

$$f(\mathbf{x}^p) = t^p \forall p = 1, \dots, N.$$

The radial basis function method provides a collection of N basis functions, one for each data point q, with the form $\phi(\|\mathbf{x} - \mathbf{x}^q\|)$, where $\phi(.)$ is a non-linear function whose form will be explored momentarily. Thus, the q^{th} function is determined by the distance $\|\mathbf{x} - \mathbf{x}^q\|$ between $\mathbf{x}$ and $\mathbf{x}^q$, which is commonly assumed to be Euclidean. The mapping's output is then interpreted as a linear combination of the basic functions, i.e. [33]

$$f(\mathbf{x}) = \sum_{q=1}^{N} w_q \phi(\|\mathbf{x} - \mathbf{x}^q\|).$$

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The goal is to discover the "weights" w_q that allow the function to traverse the data points. Combining the preceding equations yields the following weight equations:

$$f(\mathbf{x}^p) = \sum_{q=1}^{N} w_q \phi(\|\mathbf{x}^p - \mathbf{x}^q\|) = t^p.$$

The training data determines the distances $\|\mathbf{x}^p - \mathbf{x}^q\|$ between data points p and q, so the Gaussian and inverse multi-quadratic functions are localized in the sense that:

$$\phi(r) \to 0 \text{ as } |\mathrm{r}| \to \infty.$$

Even the linear function $\phi(r) = r = \|\mathbf{x} - \mathbf{x}^p\|$ is non-linear in the components of $\mathbf{x}$ in two or more dimensions. This leads to the piecewise-linear interpolating function in one dimension, which is the simplest form of precise interpolation [34].

There are good reasons to prefer localized basis functions for neural network mappings. Gaussian basis functions will be the focus of our study since, in addition to being localized, they have several other valuable analytic qualities. We can also see how to set their widths and naturally construct function approximations. To improve the predictive models' performance, we start with the RBF networks' basic structure, which performs accurate interpolation, and then we improve on it in several ways [34], [35]:

- The number of hidden M units (basis functions) does not have to equal the number of training N data points. In general, it is preferable to have M be significantly less than N.
- The training data input vectors do not have to be defined as the centers of the radial basis functions. Instead, a training algorithm can determine them.
- The width parameter does not have to be the same for all the radial basis functions. A training algorithm can also be used to determine these.
- Like an MLP, bias settings can be added into the linear sum of activations at the output layer. These will make up for the disparity between the average value of the basis function activations over the entire dataset and the actual value.

Data and Methodology

The Saudi open data platform was searched for a data set that corresponded to the scope of our project. The data set selected was from the Saudi stock market during the period from 2017 to 2019, for a total of 19 companies from main business sectors contributing to the stock market profits for the annual net profit. The data from 2017-2018 was divided into three-month time periods for a total of 4 quarters; in 2019 it was divided into the first quarter and the second quarter due to the timing of data available respective to the conduct of this project [36].

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	Sector	First quarter 2017	Second quarter 2017		Second quarter 2019
Net income	*Real Estate Mgmt. & Dev't*				
	Telecommunication Services				
	Pharma, Biotech & Live Science				
	Diversified Financial				
	…				
	Food & Staples Retailing				
	Retailing				
	Banks				
	Insurance				

TABLE I. DATASET OF NET INCOME BY SECTOR(MAIN MARKET) FROM FIRST QUARTER2017-SECOND QUARTER2019

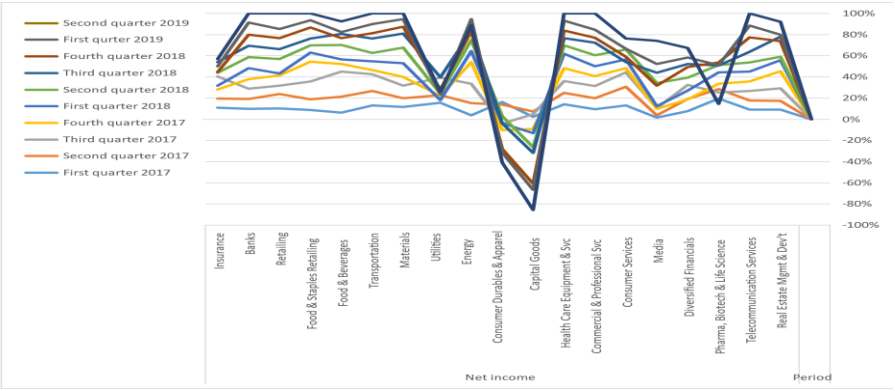

Fig. 3. the autocorrelation function of the Saudi stock market index.

The first: period, shares declined in the first quarter of 2017 in the pharmaceutical sector, in the second quarter of 2017 in capital goods, in the third quarter of 2017 in food, and in the fourth quarter of the insurance sector, In the second: period, shares declined in the first quarter of 2018 in the media sector, and in the second quarter of 2018 in important commercial services, and in the third quarter of 2018 in the public utilities sector, and in the fourth quarter of 2018 in the insurance sector, The third: period, the value of shares

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decreased in the first quarter of 2019 in the media sector and in the second quarter of 2019 in the pharmaceutical sector, Fig.3. shows the autocorrelation function of the Saudi stock market index [37].

We started by analyzing our dataset and understanding its components. But we faced a problem that the file is not correctly arranged so we started our code by taking the useful data in the study. Our task is to cluster given data to be used in the future to classify and predict sales Our algorithm's design is divided into three parts.

The first part is preprocessing on the data to be suitable for use [38]. Second part is our Activation function and we chose to be an exponential activation function using Gaussian distribution, and the reason we chose this activation function is that we want our prediction based on normal distribution depending on both the mean and the standard deviation [39]. The third part the Model itself, which has a constructor that defines its hyper parameters which are the number of clusters (output nodes), learning rate, number of epochs and the activation function we want to use, not only the Gaussian we can use any activation function.

The most important function in our model class is the Fit function which is the function that execute the feed forward and the back propagation. When the Fit function is called we call our K-means algorithm which we use from Sklearn, we save the clusters and their centroids [40]. We calculate the distances of the points from the mean to calculate the standard deviation of each cluster. Then we iterate over all the samples in each epoch and we observe the loss. Weighted sum is executed to get the output, then the error is calculated. After this we start to back propagate to update our weights and biases which were initialized randomly. When we call our model we pass our X as training set and even it's a clustering problem, however, a randomly initialized vector Y as our labels, just to observe how our Neural Network learn [41].

The choice of the inputs needs to rely on previous stock share prices. Those inputs could be taken to cover the time of the stock market exchange yet to have limited number of inputs to simply the predictive model architecture. The inputs can cover previous 7 days stock share prices, previous month share price, previous 6 months share price, and the previous year share price. More data can add more information but on the expenses of the model complexity. To select the centers and the standard deviations for the radial basis function we need to use a clustering algorithm in which the number of clusters will be the number of perceptron's and the found centroids will be the RBF centers while the distance to the centroid will determine the standard deviation. That needs to be repeated each time we increase the number of perceptron's' in the hidden layer.

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The flowchart starts with an initial number of perceptron's in the hidden layer. That is followed by a k-means clustering using the dataset to determine the RBFs' centers and standard deviations. The dataset is divided into training and testing with 80:20 ratio. More perceptron's can be added to the hidden layer to improve the accuracy while avoiding overfitting. The right number of perceptron's in the hidden layer will be used during the final training stage followed by testing to determine the predictive model performance.

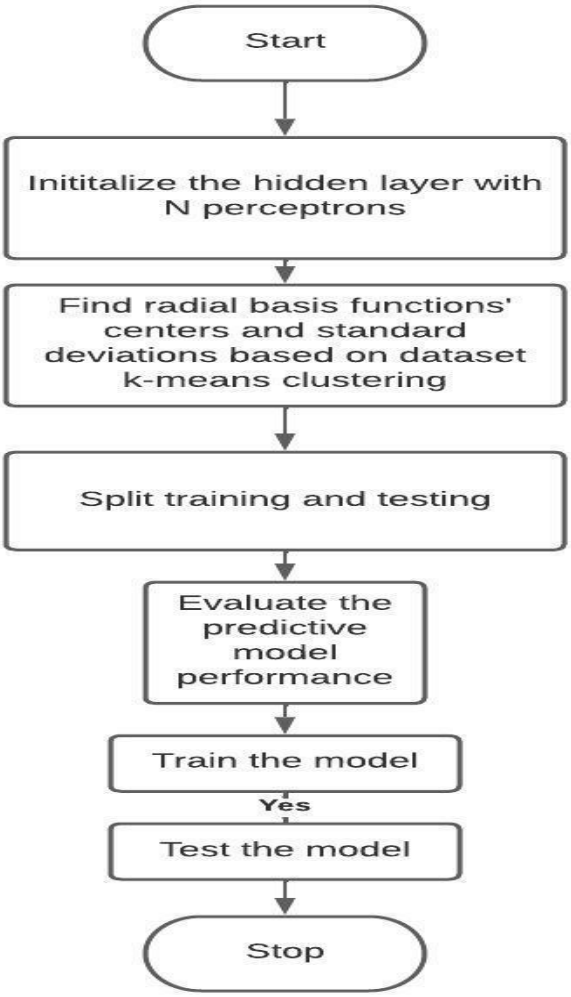

Fig. 4. **Implementation Process for the system**

Results and Discussion

The proposed model, by improving performance measures using hyperparameters, proved that the RBFNN algorithm can predict the most profitable securities for companies for the test data better compared to the ANN algorithm, linear regression, where the results show as shown in the TABLE II that the model The proposal proved the extent of its positive impact

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in predicting the profits of companies in the stock market, which is an indicator that largely mimics the direction of the Saudi stock market.

TABLE II. COMPARISON BETWEEN MODELS RESULT

Method	Task	MA	MS	RM
RBFNN	predictio	0.5	0.7	0.8
Linear Regre	predictio	0.5	0.8	0.9
ANN	predictio	0.6	0.6	0.8

From the above figure, we note that three RBFNN algorithms were used, which was an average percentage in the three cases to predict the indicators of the Saudi stock market, so the value of Root square error RMSE was predicted at 84%, the value of Mean square error MSE was predicted at 71%, and the prediction of the value of Mean absolute error MAE was at 58%, and the Linear regression algorithm, which Its proportion was large in the three cases to predict the indicators of the Saudi stock market, so the value of RMSE was predicted by 90%, the prediction of the value of the MSE by 81%, and the prediction of the value of MAE by 53%, and the ANN algorithm was used, which was a small percentage in the three cases to predict the indicators of the Saudi stock market. With an RMSE of 82%, a prediction of an MSE of 67%, and a prediction of a MAE of 62%.

After comparing the results, we conclude that the RBFNN algorithm is more accurate than its counterparts and has the lowest predictive error rate in the Saudi stock market. In addition to the advantage of the RBFNN algorithm, its speed in prediction.

We note from the confusion matrix of the model from the table below in the case of 0 = matrix the number of wrongly classified cases was 0.57675 MAE and in the case of the index in the third quartile the number of wrongly classified cases was 0.708271 MSE and in the case of 2 = classified as the number of wrongly classified cases was 0.841588 RMSE for the shares in The first quarter of the three years stock market. TABLE III shows the interference matrix.

TABLE III. CONFUSION MATRIX

	predictor values		
Actual values	1	0	classified as
	MSE	MAE	0 = matrix
	0.708271	0.57675	1 = values

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After testing the models on the test sample that came from splitting, we need to test the models on big real test data. The test data set that we use in testing our algorithms RBFNN to evaluate it and decide which one is better is the Saudi stock market dataset. It is does not look like our data set that we have used in the training, so we made some transformation on it to make the new data set like the old one. We choose RMSE to compare between the models. The final comparison, the results indicated that the RBFNN algorithm is better in the real data set in TABLE IV.

TABLE IV. 1NEW COMPARISON BETWEEN MODELS RESULT

Model	Test on testing sample	Test on real data
RBFNN	0.841	0.802
Linear Regression	0.901	0.981
ANN	0.827	1.07

Conclusion and Futuer Work

We reviewed several research articles and evaluated models related to our field of study, as well as scientific papers on neural network algorithms and the Saudi stock market, and summarized the most relevant points. In addition, we found that there is a lack of research in the area of RBFNN The number of the research that are covered in the literature review is 11 Several techniques were used to reach the appropriate prediction accuracy through the model. thus showing the accuracy of using the RBFNN model compared to the ANN algorithms, linear regression in our data set and a large real test data set.

The suggestions for some ideas that could develop the work in the future are as follows:

- Increase the number of previous datasets in the study.
- One of the proposed models for its accuracy in predicting stock market prices is Least-squares support-vector machines(LSSVM),working on it and comparing it with RBFNN may improve the study results [43].

References

[1] Alghamedi, A. and A. Misfer (2012). Assessing the impact of stock market development on economic growth in Saudi Arabia: An Empirical Analysis, Durham University.

[2] Alnodel, A.A., Khlaifah, N. and Elnafabi, H.M., 2020. Evaluating the quality of services provided by the financial controller in governmental organizations: Using the servperf model. *Journal of Governance and Regulation/Volume*, *9*(2).

[3] Abdalla, S.Z.S. and Suliman, Z., 2012. Modelling stock returns volatility: Empirical evidence from Saudi Stock Exchange. International Research Journal of Finance and Economics, 85, pp.166-179.

[4] Alshammari, T. S., et al. (2020). "Modeling and forecasting saudi stock market volatility using wavelet methods." The Journal of Asian Finance, Economics, and Business 7(11): 83-93.

[5] Alotaibi, T., et al. (2018). "Saudi Arabia stock market prediction using neural network." International Journal on Computer Science and Engineering 9(2): 62-70.

[6] Khashan, H. (2017). "Saudi Arabia's Flawed" Vision 2030"." Middle East Quarterly.

[7] Alshogeathri, M. A. M. (2011). Macroeconomic determinants of the stock market movements: empirical evidence from the Saudi stock market, Kansas State University.

[8] Lerner, J., et al. (2017). "The CMA and the Saudi stock market crash of 2006." BELLA Research Group and Saudi Capital Market Authority (CMA).

[9] Alkhaldi, B.A., 2015. The saudi capital market: The crash of 2006 and lessons to be learned. *International journal of business, economics and law*, *8*(4), pp.135-146.

[10] Liang, Y. (2021). 6 STOCK MARKET FORECASTING BASED ON AR T FORECASTING BASED ON ARTIFICIAL INTELLIGENCE TECHNOLOGY

[11] Vrbka, J. and Z. Rowland (2017). Stock price development forecasting using neural networks. SHS Web of Conferences, EDP Sciences.

[12] Loayza, R., et al. (2021). Application of Emerging Technologies in the development of a model of Neural Network for the financial forecast in the Stock Exchange of Lima, EasyChair.

[13] Padhiary, P. K. and A. P. Mishra (2011). "Development of improved artificial neural network model for stock market prediction." International Journal of Engineering Science and Technology 3(2): 1576-1581.

[14] Fallatah, Y. (2011). "Saudi Arabia stock prices forecasting using artificial neural networks." from https://ieeexplore.ieee.org/document/6041425.

[15] Sharma, D. K., et al. (2021). "Integration of genetic algorithm with artificial neural network for stock market forecasting." International Journal of System Assurance Engineering and Management: 1-14.

[16] Nti, I. K., et al. (2021). "A novel multi-source information-fusion predictive framework based on deep neural networks for accuracy enhancement in stock market prediction." Journal of Big Data 8(1): 1-28.

[17] Madhu, B., et al. (2021). "A Comparative Study of Support Vector Machine and Artificial Neural Network for Option Price Prediction." Journal of Computer and Communications 9(5): 78-91.

[18] Alturki, F. A. and A. M. Aldughaiyem (2020). "Trading Saudi Stock Market Shares using Multivariate Recurrent Neural Network with a Long Short-term Memory Layer." Machine learning 11(9).

[19] Olatunji, S., et al. (2013). "Forecasting the Saudi Arabia stock prices based on artificial neural networks model." International journal of intelligent information systems 2(5): 77-86.

[20] tadawul (2021). "tadawul KSA." Retrieved 22 NOV, 2021, from https://ar.wikipedia.org/wiki/%D8%A7%D9%84%D8%B3%D9%88%D9%82_%D8%A7%D9%84%D9%85%D8%A7%D9%84%D9%8A%D8%A9_%D8%A7%D9%84%D8%B3%D8%B9%D9%88%D8%AF%D9%8A%D8%A9_(%D8%AA%D8%AF%D8%A7%D9%88%D9%84).

[21] Pareek, V.K., Brungs, M.P., Adesina, A.A. and Sharma, R., 2002. Artificial neural network modeling of a multiphase photodegradation system. *Journal of Photochemistry and Photobiology A: Chemistry*, *149*(1-3), pp.139-146.

[22] NN, I. (2021). "5 A Friendly Introduction to [Deep] Neural Networks." from https://www.knime.com/blog/a-friendly-introduction-to-deep-neural-networks.

[23] (2021). "Neural Network." 2022, from https://www.investopedia.com/terms/n/neuralnetwork.asp.

[24] Wanjawa, B. W. and L. Muchemi (2014). "ANN model to predict stock prices at stock exchange markets." arXiv preprint arXiv:1502.06434.

[25] ANNML (2020). "What is a Neural Network in Machine Learning." Retrieved 14 Nov, 2021, from https://www.tutorialspoint.com/what-is-a-neural-network-in-machine-learning.

[26] John A. Bullinaria (2004). 22Radial Basis Function Networks.

[27] AI (2021). "30 Artificial intelligence in the stock market." Retrieved 3 Dec, 2021, from https://www.arab-cio.org/%D8%A7%D9%84%D8%B0%D9%83%D8%A7%D8%A1-%D8%A7%D9%84%D8%A7%D8%B5%D8%B7%D9%86%D8%A7%D8%B9%D9%8A-%D9%88%D8%A3%D9%87%D9%85%D9%8A%D8%AA%D9%87-%D9%81%D9%8A-%D8%B3%D9%88%D9%82-%D8%A7%D9%84%D8%A3%D9%88%D8%B1.

[28] Sbarufatti, C., Corbetta, M., Giglio, M. and Cadini, F., 2017. Adaptive prognosis of lithium-ion batteries based on the combination of particle filters and radial basis function neural networks. *Journal of Power Sources*, *344*, pp.128-140.

[29] Alzaeemi, S.A. and Sathasivam, S., 2020. Artificial immune system in doing 2-satisfiability based reverse analysis method via a radial basis function neural network. *Processes*, *8*(10), p.1295.

[30] Wu, S.-I. and R.-P. Lu (1993). Combining artificial neural networks and statistics for stock-market forecasting. Proceedings of the 1993 ACM conference on Computer science.

[31] RBFN (2020). "Radial Basis Function Networks." Retrieved 15 Nov, 2021, from https://pythonmachinelearning.pro/using-neural-networks-for-regression-radial-basis-function-networks/.

[32] Zhao, B., et al. (2018). Short-term load forecasting based on RBF neural network. Journal of Physics: Conference Series, IOP Publishing.

[33] Zemouri, R., et al. (2003). "Recurrent radial basis function network for time-series prediction." Engineering Applications of Artificial Intelligence 16(5-6): 453-463.

[34] Bullinaria, J.A., 2014. Radial basis function networks: algorithms. University of Birmingham, UK, pp.6-7.

[35] Yu, H., Xie, T., Paszczyñski, S. and Wilamowski, B.M., 2011. Advantages of radial basis function networks for dynamic system design. IEEE Transactions on Industrial Electronics, 58(12), pp.5438-5450.

[36] Data. "Available in." Retrieved 25 Mar, 2021, from https://data.gov.sa/Data/dataset/net-income-by-sector-main-market-from-first-quarter-2017-second-quarter-2019/resource/e4d1aa96-b61a-4b40-b368-a7f924f2b36b.

[37] GARCÍA, S., LUENGO, J. and HERRERA, F., 2015. Data preprocessing in data mining. Springer.

[38] Yu, H., Xie, T., Paszczyñski, S. and Wilamowski, B.M., 2011. Advantages of radial basis function networks for dynamic system design. IEEE Transactions on Industrial Electronics, 58(12), pp.5438-5450.

[39] GALLANT, S.I. and GALLANT, S.I., 1993. *Neural network learning and expert systems.* MIT press.

[40] JEKEL, J.F., KATZ, D.L., ELMORE, J.G. and WILD, D., 2007. *Epidemiology, biostatistics and preventive medicine.* Elsevier Health Sciences.

[41] PENNER, A., 2019. Fitting splines to a parametric function. Springer.

[42] Hegazy, Osman, Omar S. Soliman, and Mustafa Abdul Salam. "Lssvm-abc algorithm for stock price prediction." *arXiv preprint arXiv:1402.6366* (2014).