Determination of Optimum Artificial Neural Network in the Stock Market

Borsada Optimum Yapay Sinir Ağının Belirlenmesi

Ersin Kanat*

Abstract: Artificial intelligence applications are widely used in the field of finance as in all fields. In the field of finance, artificial neural networks are the most commonly used artificial intelligence methods for the analysis of time series. The fact that artificial intelligence methods make similar inferences to the human brain or that they are systems based on learning is the most important of their contributions to analysis. Of course, the development process of these methods is closely related to the development of technology should not be forgotten. In other words, despite all the advantages, the demand for the use of methods is now due to the fact that transactions can be done more quickly and simply. Past studies of artificial neural networks show that many of them make successful predictions. However, it is also known that the results are different. This is because there are elements that can affect the performance of the system, such as network architectures, number of layers, and educational algorithms. In this study, the optimum artificial neural network that should be established in Istanbul Stock Exchange is emphasized. How a network structure will work with better performance in Borsa İstanbul is examined. For this purpose, many analyses were carried out with network architectures, hidden layer numbers and educational algorithms. In the analysis, fundamental and technical data were used as input variables in order to predict the BIST100 index. The main variables are US Dollars, interest rates on deposits and money supply (M2). The technical variables are; MACD, RSI, Momentum and Stochastic. As a result of the study, it was observed that the use of feed-forward networks and Bayesian Regulation training algorithm would be appropriate in the analyzes made with BIST100 index. In addition, it was observed that increasing the number of hidden layers increases the performance, but it is observed that performance increase slows down if more than 5 layers are selected. Therefore, it is considered that the ideal number of layers should be 5 against the speed of the system and the problems of memorization of the network.

Structured Abstract: Numerous researches and studies have been conducted to make good and rational decisions about the future. Thanks to the studies made, significant progress has been observed and various methods have been developed in order to make the right decisions. Statistical and econometric methods constitute the majority of such studies. Many of these methods have been accepted by the scientific community

* Dr. Öğr. Üyesi, Zonguldak Bülent Ecevit Üniversitesi, Uygulamalı Bilimler Yüksekokulu, Bankacılık ve Finans Bölümü

Asst. Prof. Dr. Zonguldak Bülent Ecevit University, School of Applied Sciences, Banking and Finance

ORCID 0000-0002-9361-4495

ersinkanat44@hotmail.com

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and these methods are very important for the studies. Despite its benefits, the performance of the aforementioned methods and estimates in financial events depends mainly on the analyst.

It cannot be said that any method used enables us to reach a definitive judgment about the future. With these methods, we carry out the analyzes with the help of the available data and try to make predictions based on these data. In addition, there are numerous factors that can affect financial situations. Therefore, it is impossible to include all the factors that may be encountered and even the number of which we do not know. This is expressed as uncertainty. In order to make better decisions in environments where there are uncertainties, methods continue to be developed in this direction over time. One of the best examples of this is to try to overcome the problem with artificial intelligence applications.

Artificial intelligence applications are increasing all over the world. In the world of science, it also finds a wide range of applications in all areas. Finance is one of these areas. Artificial neural networks are a sub-branch of artificial intelligence. Due to the success it has shown in future forecasts, artificial neural networks are often used to estimate stock prices, especially on stock exchanges. When past studies are examined, it is seen that many models make successful predictions. However, it is also known that these models were established in various ways. In this case, the first question that comes to mind is which model works more efficiently. Since there are no rules regarding the optimal installation of artificial neural networks, system installation is usually carried out using past studies or experience. This study focuses specifically on how to establish a network in Istanbul Stock Exchange. It is examined how a network structure can work with a better performance in Istanbul Stock Exchange. Thus, it is desirable to provide information about the work planned for the future.

In this study, some important studies in the literature, which are thought to be relevant, are mentioned. Later, information was given about artificial neural networks and information was given on the subject. After the introduction of artificial neural networks, artificial neural network architectures, neuron numbers and educational algorithms are tried to establish an optimal network model that can be used in the stock market. For this purpose, many trials were conducted with the closing prices of the BIST100 index. Input variables used to estimate BIST100 prices; The US Dollar, interest rates and money supply (M2) as well as MACD, Stochastic, Momentum and RSI technical indicators. The period in which the analysis was conducted covers the ten years between January 2009 and December 2018. The data used are monthly data and are taken from "EVDS" website, the data distribution platform of the Central Bank of the Republic of Turkey. In this study, appropriate architecture was selected by comparing feed-forward and cascade-forward architectures first. In addition, the ideal number of hidden layers has been selected in various trials. Finally, measurements were made with 14 different training algorithms that can be performed with Matlab software and the optimum training algorithm was determined. Thus, the predictive performances achieved by the optimum network are presented.

In the comparison of network architecture, it has been observed that the feed-forward network works better than the cascade-forward network, although there is no big difference. In addition, performance has been improved by increasing the number of layers in determining the number of hidden layers. However, as it is known, too many increases in the number of layers can lead to the network memorizing. For this reason, it is stated in the literature that the number of layers 2, 3, 4 is generally sufficient or that a certain ratio of data should be calculated. In this study, 5-layer structure was ideally accepted because a 5-layer structure performed quite well and increased the number of layers did not cause great improvements. The best performers from the 14 training algorithms implemented in a 5-tier structure with the Feed-forward network are, respectively; Bayesian Regulation, Levenberg-Marquardt and Random Weight training algorithms. The random weight training algorithm, which is in third place, has more margins of error than the other two. In addition, the performance of epoch number and training time was very poor. When Bayesian Regulation and Levenberg-Marquardt are compared, the Bayesian Regulation algorithm is considered to be ideal because the epoch number and duration of the Bayesian Regulation algorithm is slightly higher than Levenberg-Marquardt, but this difference is not too high and the error rate difference between them is high.

When the performance of the system established according to the findings as a whole is examined, it can be said that the results were relatively good. It is observed that the target and output variables are zoomed in on each other in a fairly low margin of error. The system's good results show that the network is available in the analysis with BIST100. In short, the important findings obtained in the BIST100 index are that there is a correct relationship between the increase in the number of layers and good training of the network, feed-

forward networks are better than cascade-forward networks and Bayesian Regulation training algorithm gives the best results. It should be noted that the information in question may vary with different input variables. However, with the variables used in the study and the results obtained for BIST100 at the time of the study, it is thought that it can shed light on future studies.

Keywords: Artificial Neural Network, Stock Market, Structure of The Network, Estimation of Prices.

Öz: Yapay zekâ uygulamaları her alanda olduğu gibi finans alanında da oldukça fazla kullanılmaktadır. Finans alanında zaman serilerinin analizi için en fazla uygulanan yapay zekâ metodu ise yapay sinir ağlarıdır. Yapay zekâ yöntemlerinin insan beynine benzer bir çıkarım yapmaları veya öğrenmeye dayalı sistemler olmaları, analizlere sağladıkları katkılardan en önemlileridir. Tabi ki bu yöntemlerin gelişme sürecinin teknolojinin gelişmesiyle yakından ilişkili olduğu da unutulmamalıdır. Yani tüm avantajlarına rağmen yöntemlerin kullanılmasındaki talep, artık işlemlerin daha hızlı ve basit şekilde yapılabiliyor olması sayesinde. Yapay sinir ağları ile ilgili geçmişte yapılmış olan çalışmalar incelendiğinde birçoğunun başarılı tahminlerde bulunduğu görülmektedir. Ancak, elde edilen sonuçların farklı olduğu da bilinmektedir. Bunun sebebi ağ mimarileri, katman sayısı ve eğitim algoritması gibi sistemin performansını etkileyebilecek unsurların bulunmasıdır. Bu çalışmada Borsa İstanbul'da kurulması gereken optimum yapay sinir ağı üzerinde durulmuştur. Nasıl bir ağ yapısının Borsa İstanbul'da daha iyi performansla çalışacağı irdelenmektedir. Bunun için ağ mimarileri, gizi katman sayıları ve eğitim algoritmaları ile birçok analiz gerçekleştirilmiştir. Analizlerde BİST100 endeksinin tahmin edilebilmesi için girdi değişkeni olarak temel ve teknik verilerden yararlanılmıştır. Temel değişkenler; Amerikan Doları, mevduatlara uygulanan faiz oranı ve para arzı(M2)'dir. Teknik değişkenler ise; MACD, RSI, Stokastik ve Momentum'dur. Çalışma sonucunda, BİST100 endeksi ile yapılan analizlerde feed-forward network'lerin kullanılmasının ve Bayesian Regulation eğitim algoritmasının seçilmesinin uygun olacağı gözlenmiştir. Ayrıca gizli katman sayısının artırılmasının performansı arttırdığı gözlenirse de 5'ten fazla katman sayısı seçilmesi durumunda performans artışının yavaşladığı farkedilmiştir. Bu yüzden, sistemin hızı ve ağıın ezberleme sorunlarına karşı ideal katman sayısının 5 olması gerektiği düşünülmektedir.

Anahtar Kelimeler: Yapay Sinir Ağı, Borsa, Ağ Yapısı, Fiyat Tahmini.

1. Introduction

Predicting the future, making good and rational decisions has always been an important and desirable need for people. Numerous researches and studies have been carried out on the subject in order to address this need. Thanks to the studies, significant progress has been made in order to make the right decisions and various methods have been developed. In general, statistical and econometric methods have been used in such studies. Although many of these methods are accepted and very useful methods, the performance of forecasts in financial events depends mainly on the analyst.

No method used can make us reach a definitive conclusion about the future. Through these methods, we perform the analyses with the data we have today and try to see what should be and make predictions based on this data. In addition, there are numerous factors that can affect financial situations. So it's impossible to include all the factors that can be encountered that we don't even know the number of factors in the analysis. This is expressed as uncertainty. In order to make better decisions in environments where there are uncertainties, methods continue to be developed in this direction over time. One of the best examples of this is to try to overcome the problem with artificial intelligence applications.

In the world and Turkey, there is a lot of work related to artificial intelligence in the field of finance as in almost every field. These studies show that artificial intelligence applications are promising in finance. Despite the fact that the studies on the subject are still improving, good results can be obtained even in today's situation. Therefore, interest in similar studies is increasing day by day and continues to continue the development process rapidly.

Although there are many sub-branches of artificial intelligence, it is seen that artificial neural networks, genetic algorithms and fuzzy logic methods are the most used in finance. These methods can be used separately or they can be used together in some studies. The fact that methods make an inference similar to the human brain or that they are learning-based systems are the most important contributions they make to analysis. Of course, the development process of these methods is closely related to the development of technology should not be forgotten. In other words, despite all the advantages, the demand for the use of methods is now due to the fact that transactions can be done more quickly and simply.

In spite of these positive developments, it can be seen that different results were produced in some of these studies when the literature is examined. There could be a lot of reasons for that. The time interval of the data used at the beginning of these can be listed as different variables and differences in the structure of systems established with the help of artificial intelligence. Therefore, the inferences and interpretations from this study may also differ. In addition, different results can be achieved in each country's market and even in applications in different areas within a country. Therefore, a different system may be required for each market.

It is observed that the algorithms and network structures used in some of the studies were selected according to their frequent use in the literature. For example, an algorithm that is widely used in index estimates is preferred in a new study. This may be an appropriate method under normal circumstances, but this does not mean that the markets where many of these studies are done and the markets in our country will give the same efficiency.

In this study; instead of testing or comparing the validity of the neural networks, the appropriate network structure was investigated. BIST100 index was included in the study and many attempts were made at Borsa İstanbul to determine which educational algorithm and architectural structure gave better results. In short, the best network system that can be established with artificial neural networks has been tried to be established in Borsa İstanbul. Thus, it is thought that it can shed light on future studies.

2. Literature Review

Artificial intelligence has become widely used in every field. Artificial neural networks are one of the most widely used artificial intelligence applications in studies and scientific research. When the literature is examined, it is seen that there are an unlimited number of resources in the field of finance. However, many of these studies use different network architectures and algorithms. Because there are no strict rules for the modeling of artificial neural networks. Often applications are shaped by trial and error and experience. This section contains important and previously conducted studies that may be related to the subject of the study.

Kaastraa and Boyd (1996) introduced the use of artificial intelligence in the estimation of time series in their study and mentioned step by step implementation. In doing so, they tried to establish the appropriate model for the time series.

Benardos and Vosniakos (2007) conducted research on the performance of advanced feed-forward network structures. They aimed to create an appropriate architecture by experimenting with issues such as modeling of the ANN and choosing the appropriate training algorithm.

Luo et al. (2018) also worked on building a strong artificial neural network architecture. For this purpose, they have investigated an optimization system to perform the process. They have shown that the algorithm they have created for the optimization process is quite successful.

Kavzoglu (1999) tried to determine the best artificial neural network structure in general. As a result of the study, it was concluded that large-bodied networks learn quickly but are not necessary

to get better results. So according to the researcher, the network is large enough to learn information about data. The fact that it is too large does not improve the accuracy of the analysis.

Khalid and Nouredien (2014) worked on efficient structure in feed-forward artificial neural networks. However, the studies of the researchers were carried out with breast cancer data. According to their research, the increase in the number of hidden layers positively affects performance and they have seen that the 5-layer system produces the best results with breast cancer data. However, they found that the number of neurons in the layers was 1 or 2, which gave better results.

Ibrahim, Jihad and Kamal (2017) compared Back-Propagation and Levenberg-Marquardt training algorithms as they tried to determine the optimum artificial neural network. In their work, they used feed-forward artificial neural networks. Consequently, they argued that the Back-Propagation algorithm yielded better results.

Panchal and Panchal (2014) emphasized the importance of determining the number of hidden neurons in artificial neural networks and provided information on methods of determining the number of neurons. They made comparisons with different neurons and layers on actual data.

As you can see, the issue of achieving greater efficiency in the application of artificial neural networks has been a subject that has attracted the attention of researchers. Since most of these studies are about to yield efficiency in general terms, this study aimed to examine the optimum system especially for the stock market.

3. Artificial Neural Networks

The artificial neural network (ANN) is an information processing method based on the foundation of neural networks and cells in the human brain. As it is known, the process of learning, memory and obtaining results by establishing a relationship between data is carried out by nerve cells in the human brain. Artificial neural networks are simulations of these nerve cells. Because, like real nerve cells, it comes to the fore front with learning and inference based on data (Ersoy & Karal, 2012: 192).

In fact, as in the case of artificial neural networks with a single cell is not processed. Each nerve cell is related to a certain part of the problem. Artificial neural networks also consist of multiple simple process elements to solve the problem. Although the processes of these elements are seen as simple, they come together to form a network through their connections to each other and overcome difficult problems. In short, it can be thought of as cells that perform very small and simple operations to come together and perform complex operations.

3.1. Artificial Nerve Cell

Nerve cells in the human brain are composed of certain parts. These are the three basic components called cores, dendrites - acrosis and synapses. A nucleus is the part where processes and events within the cell occur. Dendrites transmit the information they receive from the axons of other cells to the nucleus of the cell. Asides, on the other hand, carry the signals from the nucleus of the cell to the dendrites of other cells. The place where the axons and dendrites come together is called synapse and all signals coming from this region are transferred to the other cell according to their effects (Yazıcı et al., 2007: 66).

Figure 1: Real and Artificial Nerve Cells (Source: Zhang et al., 2019: 3)

In short, each nerve cell has several sections and the cells communicate with each other by performing simple operations individually. Similarly, artificial nerve cells are composed of various sections. These sections are as shown in Figure 1. Inputs are the parts where the information obtained from the external world or feedback of the network is entered into the artificial nerve cell. Weights are sections in which the weight of each data is evaluated within the cell. Each entry is multiplied by the weight specified for it, and this process occurs in the collector section. Finally, various processes are performed in the activation function and outputs are obtained.

3.2. Structure of Artificial Neural Networks

Although artificial nerve cells sometimes perform the same or similar processes, sometimes they can also undertake different processes. These operations are generally very simple. The connection of nerve cells to each other can solve difficult and complex problems. A network is created by these cells coming together and communicating. This can be likened to the combination of real (biological) nerve cells to form the brain. Artificial neural networks are created by arranging artificial nerve cells into various layers.

Figure 2: Artificial Neural Network Structure (Source: Zhang and Devabhaktuni, 2003: 1341)

Figure 2 shows a sample network structure. As can be seen, all cells are located in a certain layer and communicate with other cells. Here, the number of hidden layers and the number of cells in each layer are determined by the model builder. Determining the number of layers and cells is directly related to the success and speed of the process to be performed. If they are small, the system's performance may be poor. However, the high number can also cause the system to be slow and inefficient.

The structure of networks differs with respect to the direction of information and the number of layers. As shown in Figure 3, the progress of information from entry to exit indicates that the network is feed-forward. It is also observed that only the entrance and exit layers are present. In this way, the connection of the input and output layers directly by using weighted connections without any other layer is referred to as a single layer network (Aygören, Sarıtaş & Moralı, 2012: 79).

Figure 3: Single Layer - Feed Forward (Source: <https://www.mathworks.com/help/deeplearning/ug/neural-network-architectures.html>)

Figure 4 also shows another feed-forward network structure. This type of network has one or more hidden layers. If the system needs more processing, there are hidden layers between the input and output layers to perform some operations. For this reason, networks similar to the shape are referred to as multi-layered networks as well as feed-forward.

Figure 4: Multilayer - Feed Forward (Source: <https://www.mathworks.com/help/deeplearning/ug/neural-network-architectures.html>)

In some networks, the activation functions of the neurons in the hidden layer consist of radial-based functions. Data from the input layer of the network is passed through these functions to produce information to the next layer. In the next layer, the final output is produced by weighting. Such networks are called radial-based networks. The function structure used in such networks is generally gaussian function (Dogan & Korurek, 2010: 7564).

Finally, it is also necessary to mention feed-back networks. In these networks, as with feed-forward networks, only data does not move from input to output. They have at least one feedback. That is, an output is sent back to any previous element as input.

3.3. Learning in Artificial Neural Networks

In studies with artificial neural networks, it is as important in the method to be used in the training of networks as much as the architecture of the networks. The learning of artificial neural networks is done by trial and error and a output is produced by obtaining the results closest to the results that should be found. Each nerve cell is connected to another nerve cell with a certain weight. During the training of artificial neural networks, these connection weights are also renewed and improved. The training is stopped when the outputs are within an acceptable error limit as a result of comparing them to expected outputs. The training is continued until the desired results are achieved.

Each training of the network is called cycle or epoch. The more training the network undergoes, the higher the performance. However, the most appropriate training method must be chosen because the excessive number of cycles slows down the system. There are many training rules. The most common of these are the Hebb Rule, the Hopfield Rule, the Delta Rule, and the Kohonen Rule.

The Hebb Rule is the basis of the rules of learning. According to this rule; In the case where one nerve cell receives information from another nerve cell, the bond between these cells must be strengthened if the weight of both the receiving and sending cells has the same mathematical sign. Otherwise, the bond between them must be weakened. The Hopfield Rule works in the same way. This rule also determines how much the elements' connections should be strengthened or weakened, as is the hebb rule. In Delta Rule, the weights of the connections are continuously recalculated and the average of the error frames between the target output and the actual output is minimized. Finally, the Kohonen Rule is inspired by biological nerve cells. Nerve cells compete with each other for more learning opportunities or to change their weight. The neuron that produces the greatest output becomes the winner and its weight is changed. (Anderson & McNeill, 1992: 29-30).

3.4. Process Steps Required to Model ANN

There are steps to follow in order to implement applications related to artificial neural networks. These steps can be listed as follows.

1. Step - Determination of Variables: First, the variables to be used in the execution of the application or analysis must be carefully selected. It should be noted that the variables to be used in the study will directly affect the performance of the outputs to be obtained. No matter how good the established system is, working with the wrong variables can lead to undesirable results.

2. Step - Data Collection: After determining the variables, the relevant data must be obtained in order to be included in the system. This data should also be obtained from reliable and accurate sources.

3. Step - Data Editing: The data obtained should be arranged to be used in the study. For example, in a time series study, adjustments are made according to the nature of the study, such as seasonal adjustment or conversion of data to the monthly.

4. Step - Determination of Training, Testing and Verification Data: Before analyzing, some of the data obtained must be allocated for training, some for testing, and the rest for verification. There is no definitive rule about how much should be allocated for training or testing. However, applications often use 70% of the data for education. It is also possible to find suggestions on the subject in some researchers.

5. Step - Creation of Artificial Neural Network: In this step, the ideal network architecture, optimum layer and neuron numbers and functions should be selected. Since there is no clear rule when deciding these things, it is useful to benefit from experience and literature.

6. Step - Training of Artificial Neural Network: The selection of the training algorithm to be used in the training of the network is just as important as the structure of the network. In this regard, it is necessary to work diligently and make the right decision. The proper training of the network is also very important for achieving successful results.

7. Step - Implementation of the Application: After all previous steps have been performed, the application can be performed. The results of the analysis can be reached by including the data in the created system. The outputs obtained from the application are now final outputs.

4. Application

In this study, an analysis of the stock market tried to create an optimum artificial neural network. For this reason, many experiments have been conducted on BIST100 data. However, the study not only benefited from past price movements, but also used some fundamental and technical data that were thought to affect the price of the stock market. The fundamental variables are; US dollar, interest rate and the money supply (M2). The technical variables are; MACD, RSI, Momentum and Stochastic. The data used in the study are monthly data covering the ten-year period between 2009:01 and 2018:12 and were obtained from the EVDS data platform provided by the Central Bank of the Republic of Turkey.

The work was carried out with Matlab software owned by Matworks. First, experiments were conducted on 2, 3, 4 and 5 layered structures as the number of layers. This is because the number of multiple layers is often not preferred. Because the number of multiple layers not only reduces the speed of the network and causes the network to memorize rather than learn. The trials were conducted with feed-forward and cascade-forward network architectures in matlab program. For the performance of feed-forward architecture, the `feedforwardnet`, `train` and `perform` commands in matlab were used. For other architecture, the command "`cascadeforwardnet`" was used. First of all, the educational algorithm has not been modified and the architectures have been compared by default.

As a result, 5-layer structures performed more than 2, 3, and 4-layer structures. This means that increasing the number of layers improves performance. However, as previously stated, 5 layers are ideal to prevent the network from memorizing. In addition, when the number of layers 5 was accepted, the performance of the feed-forward network was better than the performance of the Cascade-forward network. The architectures in question are shown in figure 5.

Figure 5: Feed-Forward and Cascade-Forward Network Architectures (Matlab Image)

In line with the results obtained, 14 different training algorithms were tested in Matlab environment with feed-forward network architecture and 5-tier structure. 70% of the data was used for training, 20% for verification and 10% for testing. The results of the training algorithms tried in the related structure are shown in Table 1.

Table 1: Results of Educational Algorithms

	Epoch	Duration (sec)	Error Rate
Trainbfg	16	0	0,00872
Trainbr	306	16	0,000504
Traincgb	9	0	0,0153
Traincgf	15	0	0,0131
Traincgp	31	3	0,00974
Traingd	987	6	0,0263
Traingdm	1000	6	0,0219
Traingda	96	0	0,048
Traingdx	85	0	0,0301
Trainlm	16	1	0,000981
Trainoss	17	0	0,00776
Trainr	1000	1075	0,00585
Trainrp	34	0	0,0157
Trainscg	31	1	0,0106

The three variables that provide the best performance in training algorithms are shown in Table 2. Accordingly, although the best performance in epoch is Levenberg-Marquardt algorithm, the error rate of Bayesian Regulation algorithm is much lower. There is a significant difference in epoch and error rates between Bayesian Regulation and Random Weight algorithms. In this case, it

is thought that the variable that should be selected in an analysis to be performed with the relevant variables in BIST100 should be Bayesian Regulation.

Table 2: Top Three Training Algorithms for Best Performance

	Epoch	Duration (sec)	Error Rate
Trainbr (Bayesian Regulation)	306	16	0,000504
Trainlm (Levenberg-Marquardt)	16	1	0,000981
Trainr (Random Weight / Bias Rule)	1000	1075	0,00585

In Figure 5 and figure 6, the performance of the system and training is seen. What should not be forgotten here is that there is no guarantee that the system can predict in this way for the future. Here, only the existing and the realized BIST100 data (Target & Output Data) can be traced and shown how close they are to each other.

Figure 6: Performance of Artificial Neural Network

Figure 7: Neural Network Training Regression

5. Conclusion

There are no clear and specific rules for the construction of artificial neural networks. Network structures are generally determined by trial and error. Similarly, issues such as selection of training algorithm are also closely related to user experience. For this reason, in the study, some experiments for BIST100 index have been made and an ideal structure has been investigated. Exchange rate, money supply and interest rate data, which may affect the BIST100 index, were evaluated monthly. In addition to the aforementioned variables, some technical indicators were added and used as input variables. These technical indicators include; macd, rsi, stochastic and momentum.

Experiments have been conducted the study continuously with network architecture, number of layers and educational algorithms. As a result of the research, it was found that the feed-forward network structure can help to get good results in the stock market index. In addition, it has been observed that system performance has increased by increasing the number of hidden layers. In addition, Bayesian Regulation has been accepted as the best algorithm for education.

It should be noted that the information in question may vary with different input variables. However, with the variables used in the study and the results obtained for BIST100 in the period under consideration, it is thought that it may shed light on future studies.

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