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Artificial Intelligence Approaches for Performance Prediction of Investment Companies in the Iranian Capital Market

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Abstract

Investment companies listed on the Iranian Stock Exchange play a crucial role within the nation's capital market. Consequently, the development of a robust model for identifying, evaluating, and ranking these companies using artificial intelligence (AI) techniques offers a valuable approach to enhancing investment quality. This study employs AI models to assess and rank investment companies listed on the Iranian Stock Exchange. Specifically, an Adaptive Neuro-Fuzzy Inference System (ANFIS) algorithm is proposed. Each input variable undergoes a fuzzification process, involving the definition of membership functions. An ANFIS model is then constructed, utilizing these ten input variables—company management characteristics (Management), capital market financial variables (Financial), internal control quality (IQC), industry factors (Industry), competitive situation (Competitive), quality management (QM), credit and economic situation (CES), accrual financial ratios (AFR), cash financial ratios (CFR), and capital market ratios (CMR)—to predict the performance of investment companies (Performance) as the output variable. The performance of the ANFIS model is subsequently compared with that of a neural network. The results indicate that the ANFIS method outperforms the neural network.

Keywords: Artificial Intelligence, Stock Exchange, Prediction, ANFIS

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1. Introduction

Investment is a fundamental driver of sustainable economic growth and development. Within the capital market and stock exchange, holding companies and investment firms play a critical role as financial intermediaries. Assessing the performance of these entities is essential for researchers, financial managers, and investors seeking to mitigate investment risk through informed share purchases. Establishing appropriate performance evaluation criteria is a key concern in contemporary investment management and a foundational step in data envelopment analysis. However, investment decisions should not rely solely on high returns (Sedighi, 2014). Given the systemic and unsystemic risks inherent in the Iranian capital market and recent market developments, investment companies play a particularly significant role. As professional investment managers, these companies can contribute substantially to mitigating uncertainties surrounding the market's future through informed perspectives and strategic planning. Their capacity to acquire, analyze, and process market information, culminating in logical stock market transactions, can serve as a benchmark for other market participants, thereby enhancing overall capital market efficiency. Furthermore, the development of the stock exchange is recognized as a crucial instrument for achieving sustainable economic development, a primary objective of governments. Investment companies contribute to this goal by influencing price discovery, driving stock prices towards their intrinsic value, and fostering market efficiency and stability. By pooling public capital and channeling savings into productive investments, these companies can also help curb inflation. This approach avoids injecting new money into the economy, instead directing existing funds towards national development. Consequently, through strategic investments and reduced government expenditures, investment companies can play a constructive role in national capital formation and economic growth. Additionally, they facilitate capital allocation across diverse sectors, fostering a more efficient capital market and promoting healthy competition with the money market. As performance evaluation is critical for organizational survival, the absence of an effective system can be detrimental (Tari-Verdi et al., 2013). Moreover, according to Article 6 of the Fourth Development Plan's quantitative objectives, productivity improvement is a key driver of economic growth. Therefore, evaluating the efficiency of investment companies, as vital economic institutions, is essential for national economic assessment and planning. Considering their potential for generating superior returns compared to the money market, investors should prioritize the expansion of investment company activities in the current economic climate (Saghafi et al., 2018).

A stock exchange serves as an organized and regulated capital market where shares of companies, government bonds, and securities from reputable private institutions are traded under specific rules and regulations. A key characteristic is the legal protection afforded to savers and investors, coupled with stringent requirements for capital seekers. Functioning as a hub for mobilizing private sector savings and liquidity for long-term investment projects, the stock exchange also provides a reliable platform for investors to allocate surplus funds. This can be achieved through equity investments in companies or by acquiring government bonds and securities from reputable institutions, ensuring relatively secure returns.

Manufacturing companies, engaged in the production of specific goods, are listed within designated industry sectors on the stock exchange and are identified by their company name and unique code. In contrast, investment companies function as financial intermediaries,

typically lacking direct production activities. Instead, they provide financial support to manufacturing and industrial companies through equity investments. Currently, the stock exchange lists 239 active investment companies and funds, alongside 621 manufacturing companies. Furthermore, provisions have been made for the listing of service companies (Securities and Exchange Organization website[†]).

In recent years, numerous studies have explored the performance evaluation of investment companies and funds. These studies (Mombini et al., 2019; Saghafi et al., 2018; Tari-Verdi et al., 2013; Sedighi et al., 2013; Ma et al., 2016; Nipa et al., 2010; Hu et al., 2009, etc.) have primarily focused on evaluating company performance using quantitative variables, often neglecting other relevant quantitative and qualitative factors. Therefore, this study, drawing upon theoretical foundations and expert opinions, aims to comprehensively identify all dimensions and factors that influence the performance of investment companies within the Iranian capital market. Furthermore, previous research has predominantly employed data envelopment analysis or linear and parametric models for performance evaluation, overlooking alternative modeling approaches. Consequently, this research, in its second phase, seeks to measure and rank these factors using a variety of data mining models, including data envelopment analysis, neural networks, fuzzy logic, and the adaptive neuro-fuzzy approach, ultimately comparing these models to determine the most effective evaluation methodology.

In light of the aforementioned issues, this research aims to predict the performance of investment companies within the Iranian capital market using an artificial intelligence approach. Accordingly, the central research question is: How can a comprehensive model, based on artificial intelligence and data mining techniques, be designed to evaluate and rank investment companies listed on the Iranian Stock Exchange?

2. Literature Review

Firoozan et al. (2023) examined the performance of listed companies, focusing on the shareholder structure and the role of banks within specific industries, including cement, pharmaceuticals, and chemicals. Based on their findings, they provided industry-specific recommendations. This research utilized data from 26 listed manufacturing companies spanning the period from 2009 to 2013. The results indicated that bank involvement positively influenced company performance, although the magnitude of this effect varied across industries and according to the type of bank.

Nabizade et al. (2022) investigated the performance of listed companies, employing a hybrid model to assess the default risk of companies listed on both the stock exchange and the over-the-counter market during the period 1386-1387, following their transfer to the basic market in accordance with Iranian capital market regulations. Initially, the Merton model, a structural model, was utilized to measure default risk. Subsequently, the results were compared with those obtained from the Altman Z model, a non-structural model. Regression analysis of various financial ratios was then conducted to identify significant variables, and the Merton and Altman Z models were compared both individually and in combination using statistical methods. The findings demonstrated that the hybrid model provided a more accurate prediction of default risk compared to either the structural or non-structural models alone. Integrating the results of both the Merton and Altman Z models into the hybrid model enhanced its statistical

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power. Consequently, the adoption of a hybrid model facilitates the allocation of resources by banks and credit institutions to financially sound companies with reduced risk.

Hashemi et al. (2021) aimed to explain company value using performance variables, the governance system, and the audit committee, employing the Least Angle Regression (LARS) machine learning method. Additionally, they sought to predict company value using both the linear Lasso method and the nonlinear Gaussian process method, intending to aid managerial and investor decision-making. To achieve this, 208 firm-years of data from companies listed on the Tehran Stock Exchange were utilized, covering the seven-year financial period from 1390 to 1396 (2011 to 2017). The initial results indicated that performance criteria possessed a greater capacity to explain company value compared to governance system and audit committee criteria. Furthermore, the study demonstrated the high predictive power of machine learning methods in forecasting company value, with the nonlinear Gaussian process method outperforming the linear Lasso method.

Heshmat et al. (2021) aimed to develop a comprehensive model for evaluating the financial, governance, and social responsibility performance of companies, offering a novel perspective on performance assessment. Following a review of the existing literature, a conceptual model was constructed, incorporating six distinct approaches and encompassing 25 components (indices). To validate the model and determine the weights of its constituent approaches, 15 experts employed the Analytic Hierarchy Process (AHP). Subsequently, the Shannon entropy method was utilized to assign weights to the components (indices) within each approach. Quantitative data from a sample of 180 companies listed on the Tehran Stock Exchange was used to implement this model. The findings revealed that the economic approach and the social responsibility approach received the highest and lowest weights, respectively, in the comprehensive evaluation of companies. Similarly, the price-to-earnings (P/E) ratio exhibited the highest weight among the integrated approach components. The results of this study suggest that ranking companies based on this comprehensive model can provide capital market participants with a multifaceted perspective and informed judgment.

Yaghoubian et al. (2021) aimed to present a contingency model for evaluating company performance, emphasizing the role of modern management accounting tools. Research data was collected from the financial statements and other reports of 85 companies listed on the Tehran Stock Exchange, spanning the period from 1394 to 1396. Additionally, a questionnaire was distributed among the financial managers of these companies at the end of 1396. Structural equation modeling and Smart PLS software were employed to test the proposed model. The results demonstrated that the utilization of modern management accounting tools had a positive and significant effect on company performance. Furthermore, the findings indicated that three contingency factors—market competition, environmental uncertainty, and company size—significantly and positively moderated the relationship between the use of modern management accounting tools and company performance.

Nasiri et al. (2019) investigated the financial performance of investment companies in Iran. This study, which examines and categorizes the activities of Iranian investment companies, proposes an evaluation methodology tailored to the diverse operational domains of these entities. Utilizing information from investment companies listed on the Tehran Stock Exchange, the research categorized activities into three primary areas: listed investments, unlisted investments, and project investments. Appropriate measurement criteria for each category were identified through a review of the scholarly literature and expert consultation. Company performance was measured using Tobin's Q ratio and return on assets (ROA). Data

regression analysis was subsequently conducted using econometric techniques. The analysis based on Tobin's Q ratio revealed that listed investments exerted the most significant impact on company performance, while the other two areas received less investor attention. Conversely, the ROA-based analysis indicated that both stock market investments and project investments significantly contributed to company performance.

In their study, Firoozan et al. (2021) presented an adjustable fuzzy network data envelopment analysis (DEA) approach for ranking investment companies and evaluating the performance of listed companies. This paper introduces a novel methodology for assessing and ranking decision-making units (DMUs) with a two-stage network structure in the presence of imprecise and ambiguous data. To achieve this, a two-stage network DEA model was adapted to propose a new approach: fuzzy network DEA (FNDEA).

Kumaran et al. (2021) prioritized the financial performance indicators of initial public offering (IPO) companies using VIKOR-CRITIC techniques. The primary objective of this paper was to employ multi-criteria decision making (MCDM) techniques to enhance the quality of financial decision-making and improve the resulting choices. The ranking generated by the VIKOR-CRITIC approach enables investors to identify top-rated listed companies and facilitates inter-company comparisons based on crucial representative criteria derived from a complex set of financial performance measures.

Samen et al. (2021) presented a novel multi-criteria decision-making technique, employing the technique for order preference by similarity to ideal solution (TOPSIS) approach within a fuzzy Pythagorean environment, for the selection of optimal investment companies. The proposed technique was applied to rank investment companies, enabling investors to make informed investment decisions based on their preferred criteria.

Kwon et al. (2020) examined mutual fund investments in private companies, utilizing private company data from 2000 to 2019. They concluded that mutual funds, seeking higher risk-adjusted returns, and venture capitalists, seeking new investors to justify higher valuations, invest in companies seeking additional capital to delay IPOs.

3. Research Methodology

The current research model employs the adaptive neuro-fuzzy inference system (ANFIS). This hybrid artificial intelligence model integrates the functionalities of fuzzy logic and neural networks. Introduced by Jang in the 1990s, ANFIS is recognized as a robust methodology for modeling and controlling complex systems. The ANFIS model comprises two primary stages:

1) Data Fuzzification: In this stage, the ANFIS system processes input data and incorporates fuzzy information through IF-THEN rules. ANFIS effectively learns to generate these fuzzy rules based on the input data.

2) Weight Optimization and Adaptation: This stage involves the automatic optimization of weights associated with the model's predictions. This optimization and adaptation process enhances the accuracy of the ANFIS model.

The ANFIS method is applicable to forecasting, control, optimization, and decision-making problems across diverse domains, including finance, neuroscience, and engineering. Consequently, this research focuses on developing a model for constructing optimal portfolios and trading strategies. Leveraging the ANFIS model facilitates the analysis of intricate patterns within the financial market and the design of optimal trading strategies. By combining fuzzy

precision with neural network capabilities, this model aids in intelligent decision-making and enhances efficiency.

Generally, the construction of a fuzzy inference system within the ANFIS model proceeds as follows

Initially, the independent variables—in this study, six variables comprising initial price, highest price, lowest price, closing price, trading volume, and final price—are designated as model inputs. Each input variable undergoes a fuzzification process, wherein membership functions are defined. Subsequently, fuzzy rules are formulated based on the data. A weight is then calculated for each rule, employing the Sugeno implication (minimum and Mamdani product) and integrating the constituent parts of the fuzzy rule. Notably, due to its convenience and acceptable accuracy, the Mamdani implication is utilized within the ANFIS algorithm to assess the accuracy of fuzzy rules, a stage termed the implication process. In essence, while the input values are known, the output value remains undetermined. By inputting the known values into the membership functions corresponding to the preconditions of the fuzzy rules, a parameter is calculated. This parameter is then multiplied by the output membership function (where the exact output value is unknown) using the Mamdani implication, resulting in a distinct membership function for each fuzzy rule. In the subsequent step, the membership functions calculated for each fuzzy rule are aggregated using the maximum t-norm, yielding a fuzzy set (the aggregation step). Finally, a defuzzification process is performed, producing a crisp output. The pseudocode for implementing the proposed algorithm is as follows.

```
BEGIN   /* ANFIS algorithm */
    Generate initial population
    Compute fitness of each individual
    WHILE NOT finished DO
    BEGIN   /* produce new generation */
        FOR population_size / 2 DO
        BEGIN    /* reproductive cycle */
            Select two individuals from old generation for mating
                /* biassed in favour of the fitter ones */
            Recombine the two individuals to give two offspring
            Compute fitness of the two offspring
            Insert offspring in new generation
        END
        IF population has converged THEN
            Finished: = TRUE
    END
END
```

Figure 1. ANFIS Algorithm pseudocode

4. Findings

In this section, following data definition and preprocessing, the prepared data is input into the system. The system's output is evaluated using the mean squared error (MSE) and its root mean squared error (RMSE). The results are presented in three graphical representations and as an average error percentage. In the proposed method, the input data was partitioned into two subsets: training and testing data. In the design of the hybrid network model, ten input

variables—company management characteristics (Management), capital market financial variables (Financial), internal control quality (IQC), industry factors (Industry), competitive situation (Competitive), quality management (QM), credit and economic situation (CES), accrual financial ratios (AFR), cash financial ratios (CFR), and capital market ratios (CMR)—were utilized, with the performance variable of investment companies (Performance) serving as the model's output variable. The input data was transformed into fuzzy numbers.

To construct the model, an initial fuzzy inference system (FIS) was designed using the training data, followed by the generation of corresponding membership functions. Specifically, the membership functions for the company management variable (Management), spanning the range of 0 to 1, were generated using Gaussian functions and the fuzzy c-means (FCM) clustering method. Based on the data, this variable was clustered into ten distinct intervals.

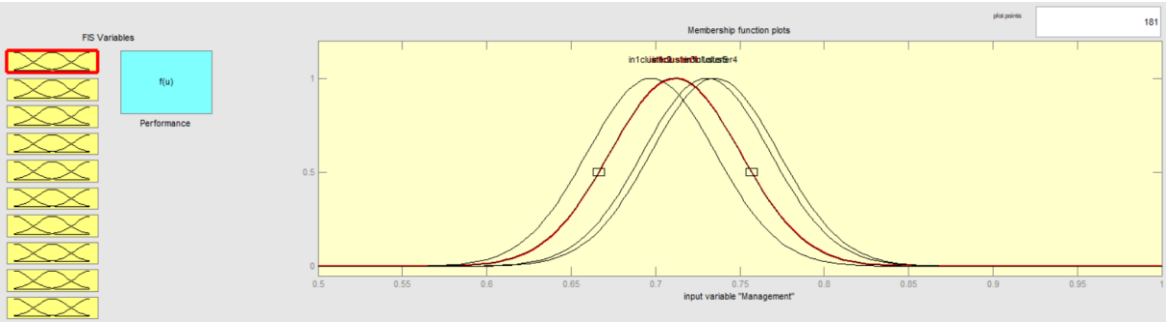


Figure 2. Management (FIS) Membership Functions

Similarly, the membership functions for the capital market financial variables (Financial) were generated within the range of 0 to 1, utilizing Gaussian functions and clustering the data into ten distinct intervals.

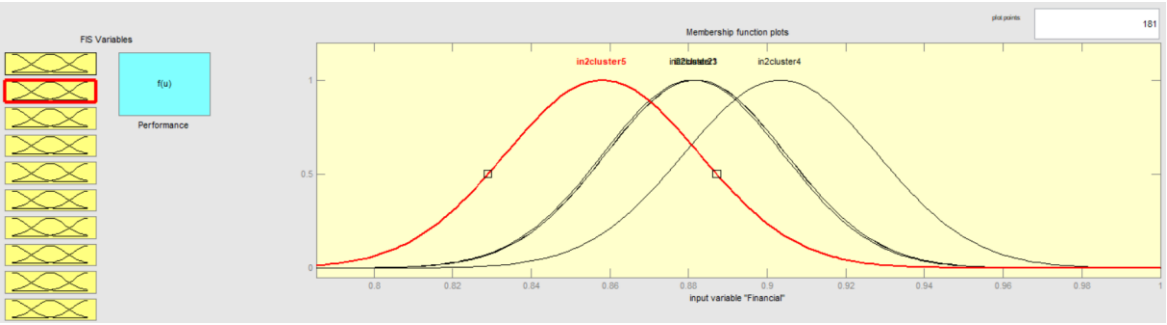


Figure 3. Financial Variables (FIS) Membership Functions

Membership functions for the IQC variable were generated within the range of 0 to 1, utilizing Gaussian functions and clustering the data into ten distinct intervals using the FCM method.

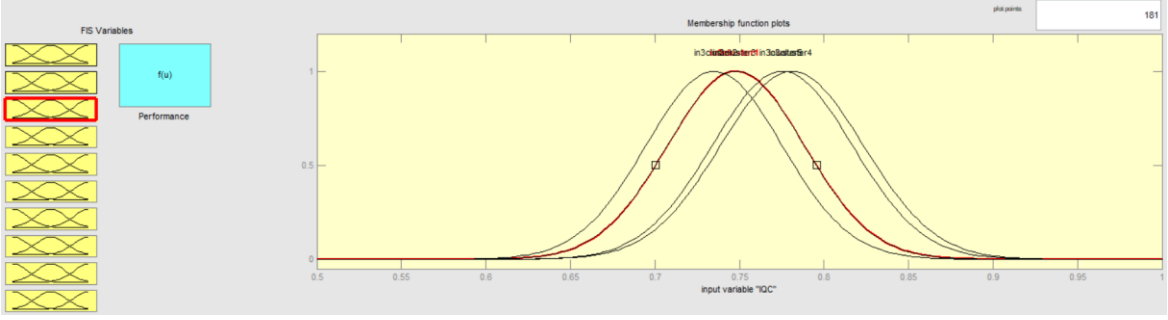


Figure 4. IQC (FIS) Membership Functions

Membership functions for the industry factor variable (Industry) were generated within the range of 0 to 1, utilizing Gaussian functions and clustering the data into ten distinct intervals using the FCM method.

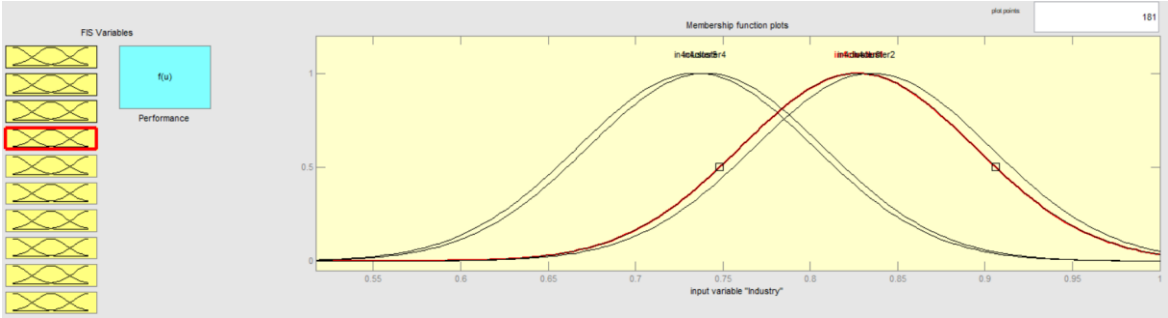
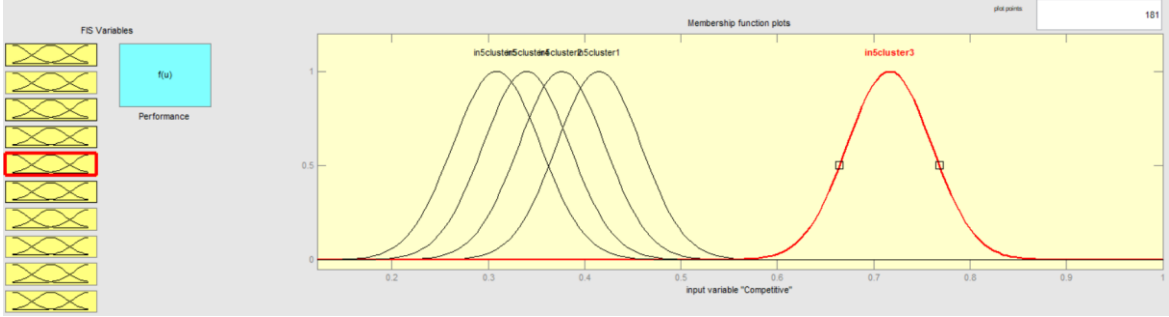
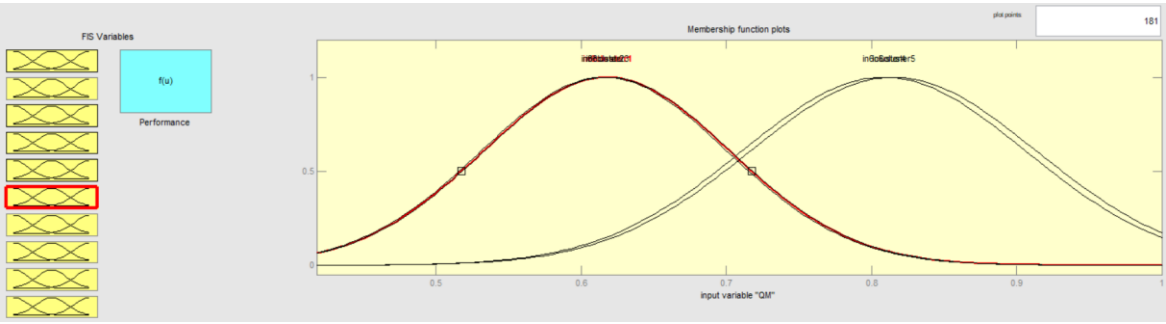


Figure 5. Industry Factors (FIS) Membership Functions

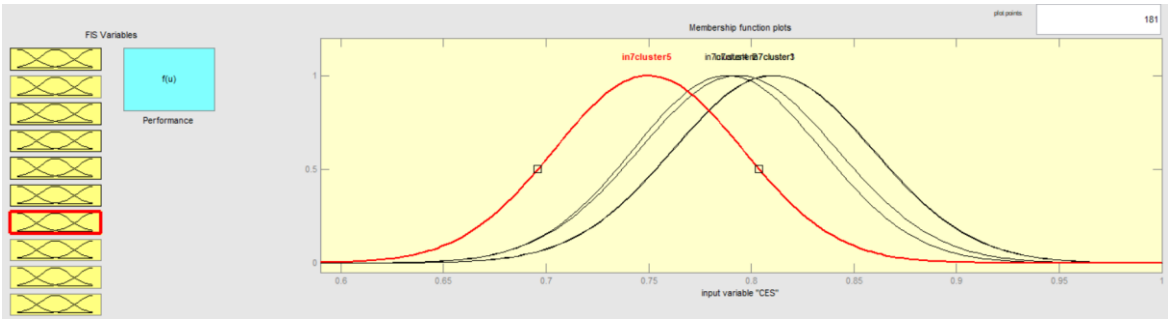
Membership functions for the variables of competitive situation, QM, CES, AFR, CFR, and CMR were generated within the range of 0 to 1, utilizing Gaussian functions and clustering the data into ten distinct intervals using the FCM method.



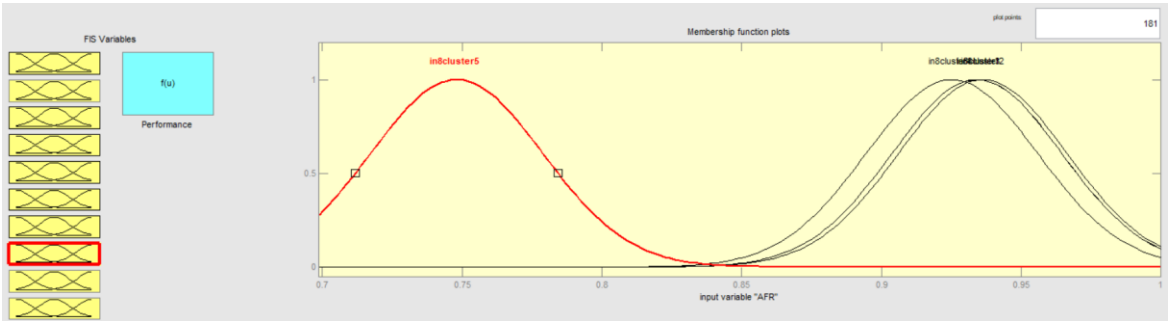
(a)



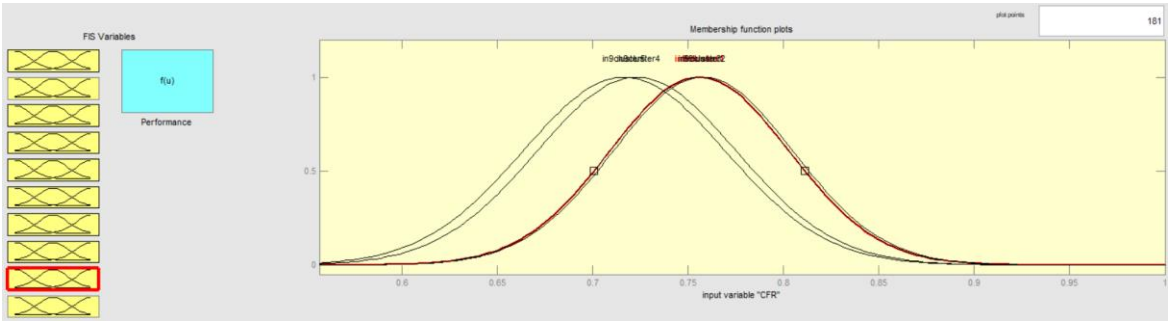
(b)



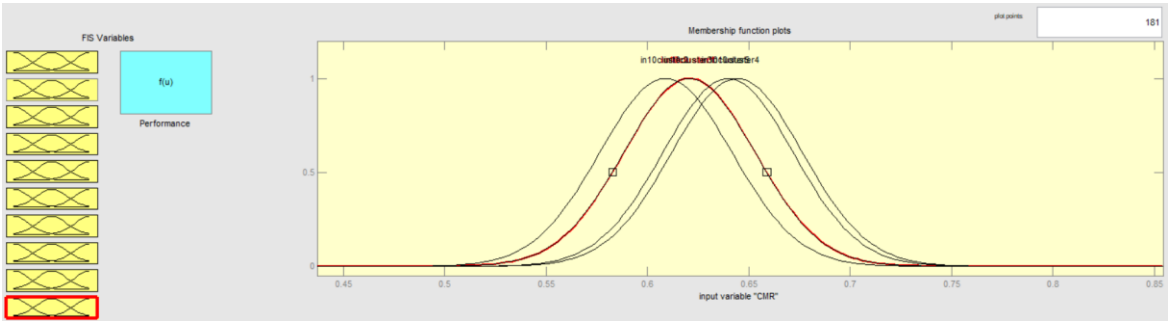
(c)



(d)



(e)



(f)

Figure 6. Membership Functions: Weights (FIS) for Competitive Situation (a), QM (b), CES (c), AFR (d), CFR (e), and CMR (f)

In this research, a Sugeno-type neuro-fuzzy inference system was employed. Ten membership functions were defined for each input, resulting in the creation of ten rules. The GENFIS3 function was used to generate the fuzzy inference system. The structure of the neuro-fuzzy inference system used in this study is depicted in Figure 7. Modeling was performed using this method within the MATLAB software. The final ANFIS model in this study processes six input variables, which are initially subjected to fuzzification, wherein membership functions are defined. Subsequently, the implication process results in the formation of ten fuzzy rules.

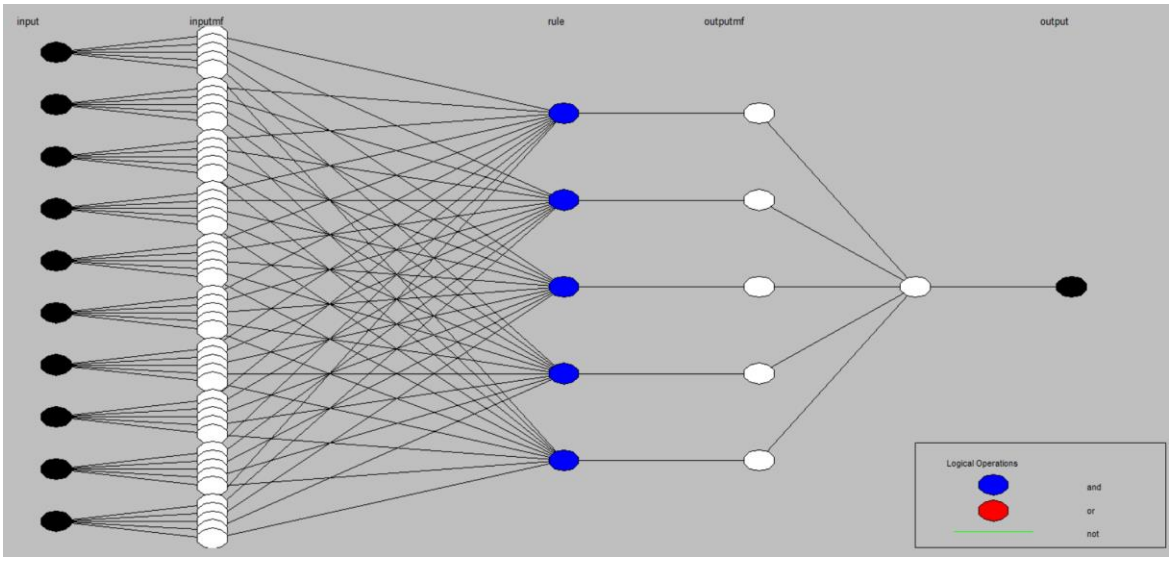


Figure 7. ANFIS Model Structure for Investment Company Performance Prediction with Ten Input Parameters

Figure 8 illustrates the nature and extent of input parameter influence on investment company performance prediction.

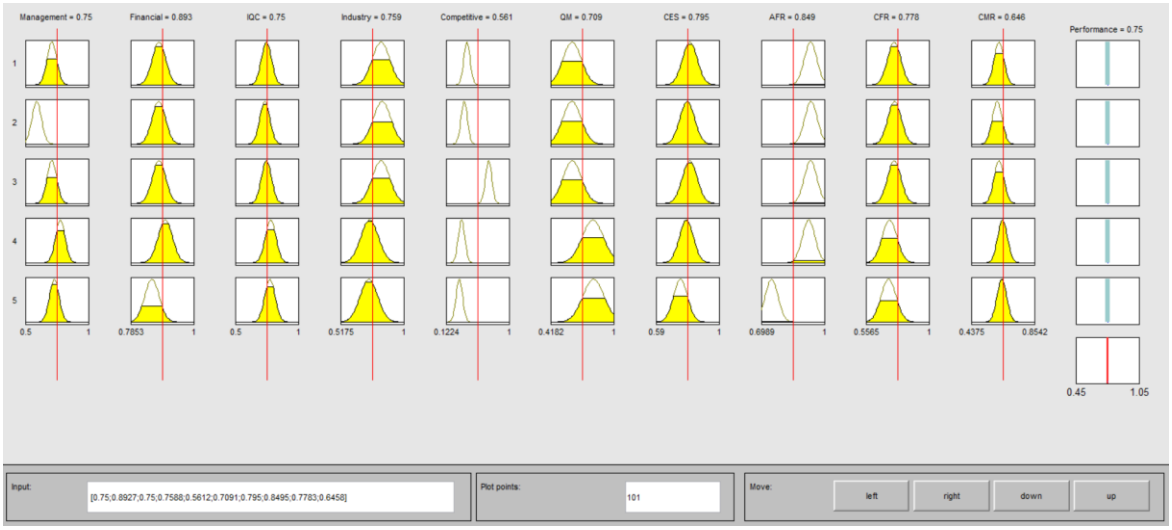


Figure 8. Final ANFIS Model for Investment Company Performance Prediction

In the algorithm training process, 70% of the data was designated as the training dataset. Subsequently, the remaining test data, which was not used during model training, was input into the model to evaluate its performance. The accuracy of the algorithm was assessed by determining the Root Mean Squared Error (RMSE) between the actual and predicted values within the studied interval. Finally, the investment company performance prediction model was constructed using ten input parameters. The performance of the ANFIS method was compared

to that of a neural network, and the results are summarized in Table 1. The analysis of the two algorithms revealed that ANFIS outperformed the neural network.

Table 1. Performance Summary of Implementation Methods

Method	Training data		Test data		Verification data	
	RMSE	Error percentage	RMSE	Error percentage	RMSE	Error percentage
Statistical Methods	0.00412	18.53%	0.00462	19.55%	0.00306	18.14%
Neural Network	0.00351	16.84%	0.00349	17.32%	0.00306	16.25%
Fuzzy Neural Network	0.00293	16.25%	0.00288	16.94%	0.00252	15.82%

5. Conclusion

Investment companies listed on the Iranian Stock Exchange play a crucial role within the nation's capital market. Consequently, the development of a robust model for identifying, evaluating, and ranking these companies using artificial intelligence (AI) techniques offers a valuable approach to enhancing investment quality. To construct a comprehensive model for identifying, evaluating, and ranking investment companies on the Iranian Stock Exchange, AI models can be effectively integrated. These models may encompass a variety of algorithms, including neural networks, fuzzy neural networks, and statistical methods. The application of AI models for identifying, evaluating, and ranking investment companies on the Iranian Stock Exchange, owing to their learning capabilities, high-speed information processing, and high accuracy in data analysis, can provide valuable insights into the investment quality of these companies. Given the ability of AI models to identify, evaluate, and rank investment companies on the Iranian Stock Exchange, these companies can be ranked accurately and transparently based on stock value and financial performance. Furthermore, the development of a predictive model using AI techniques for evaluating investment companies on the Iranian Stock Exchange can assist investment managers in making more informed investment decisions within the country's capital market. Subsequently, an ANFIS algorithm was proposed. Initially, independent variables—company management characteristics, capital market financial variables, internal control quality, industry factors, competitive situation, management quality, credit and economic situation, accrual financial ratios, cash financial ratios, and capital market ratios—were designated as model inputs. Each input variable underwent a fuzzification process, involving the definition of membership functions. Furthermore, a neuro-fuzzy inference system was constructed, utilizing ten input variables: company management characteristics (Management), capital market financial variables (Financial), internal control quality (IQC), industry factors (Industry), competitive situation (Competitive), quality management (QM), credit and economic situation (CES), accrual financial ratios (AFR), cash financial ratios (CFR), and capital market ratios (CMR), with the performance variable of investment companies (Performance) serving as the output variable. Finally, the performance of the ANFIS method was compared with that of a neural network. The comparative analysis revealed that the ANFIS method outperformed the neural network

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