A Comparison between Fuzzy Inference Systems for Prediction (with Application to Prices of Fund in Egypt)

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ABSTRACT
This paper outlines the basic differences between the Fuzzy logic techniques, including Mamdani , Sugeno fuzzy inference system models and Adaptive Neuro-Fuzzy Inference System (ANFIS). The main motivation behind this research is to assess which approach provides the best performance for predicting prices of Fund. Due to the importance of performance in Economy, the Mamdani , Sugeno models and ANFIS are compared with the actual values. Fuzzy inference systems (Mamdani , Sugeno and ANFIS fuzzy models) can be used to predict the weekly prices of Fund for the Egyptian Market. The application results indicate that (ANFIS) model is better than that of Mamdani and Sugeno . The results of the three fuzzy inference systems (FIS) are compared.

Keywords
Prices of Fund, ANFIS model, Fuzzy Inference System (FIS), Fuzzy Logic, Mamdani model, Sugeno model.

1. INTRODUCTION
Due to the ever-changing economic environment, it is noticed that the change happens in many periods measured by years, months, weeks and days. However, it so happens that a sudden change occurs, such as the recent world economic crisis that has had its serious consequences. Thus, the importance of building models for forecasting lies in the expectation of such crises. The Fuzzy logic is closer in spirit to human thinking and natural language than conventional logical systems are. The Fuzzy Logic method is a relatively modern method. It depends on the obscurity logic which is one of the ways of logic.

An adaptive Neuro-Fuzzy inference (ANFIS) system, which was used for rainfall-runoff modeling for the Nagwan watershed in the Hazaribagh District of Jharkhand, India, was used by Kumar [1]. Bireka [2] developed a fuzzy logic-based approach to leakage forecasting in the water industry. Alvisi [3] showed water level forecasted through Fuzzy Logic and Artificial Neural Network Approaches. Aqil [4] used A Takagi-Sugeno Fuzzy System for the Prediction of River Stage Dynamicsmes. Keskin [5] applied Fuzzy Logic approaches to flow Predicted Dim Stream. Mahabir [6] applied Fuzzy Logic for Forecasting Ice Jam Risk at Fort Mcmurray. A comparative study of statistical and neuro-fuzzy network models for forecasting the weather of Goztepe, Istanbul, Turkey, was presented by Tekta [7] A time series prediction model for daylight interior illuminance obtained using Adaptive neuro fuzzy inference system (ANFIS) was presented by Kurian [8].

A fuzzy logic-based system to predict bankruptcy for one, two and three years before the possible failure of companies was used by Korol [9]. Sajfert [10] exemplified the possibility of applying fuzzy logic into the process of decision making regarding the selection of executive managers. Reliable prediction of sales can improve the quality of business strategy by Chang [11]. Fuzzy approach for risk evaluating and forecasting in accidents caused by working with vehicles such as lift truck was used by Naieni [12]. Pasila [13] used Neuro-Fuzzy Approaches for Forecasting Electrical Load. A new peak power optimization algorithm of the electric energy consumption with nonlinear prediction is presented by Dankovi´c [14]. Ferreira [15] aimed to develop an algorithm using fuzzy sets to predict the estrus in dairy cows. Zaher [16] compared Mamdani and Sugeno Fuzzy Inference Systems for Prediction (with Application to Prices of Fund in Egypt). Kaur [17] shows that Sugeno results for air conditioning system are relatively better than those of Mamdani.

From previous studies, it is observed that there are many studies that have used fuzzy logic in various fields. However, no comparison was found between (ANFIS), Mamdani and Sugeno fuzzy inference system in predicating investment fund prices. This Paper provides a comparison between (ANFIS), Mamdani and Sugeno fuzzy inference systems in predicting investment fund prices

2. MAMDANI FIS VS SUGENO FIS
In terms of the inference process, there are two main types of Fuzzy Inference Systems (FIS): the Mamdani [18] and the Sugeno type [19].

In terms of use, the Mamdani FIS is more widely used mostly because of the reasonable results with a relatively simple structure it provides, and the intuitive interpretable nature of the rule base [20]. Since the consequents of the rules in a Sugeno FIS are not fuzzy, this interpretability is lost; however, the Sugeno FIS's rules' consequents can have as many parameters per rule as input values, which results in more degrees of freedom in the design than those of Mamdani and, in turn, provides the system's designer with more flexibility in the design of the system [21].

In many decision support applications, it is important to guarantee the expressive power, easy formalization and interpretability of Mamdani-type fuzzy inference systems (FIS) while ensuring the computational efficiency and accuracy of Sugeno-type FIS [22]. Hence, the fact that a Mamdani FIS can be seen as a function that maps the system's input space into its output space ensures that there exists a Sugeno FIS that can approximate any given Mamdani FIS with an arbitrary level of precision. It is beyond the scope in this paper to explain in detail the formalisms of this comparison. For a comprehensive comparison and description on several approximate reasoning methods, including Mamdani FISs and Sugeno FISs, see [23]. To sum up, the main motivations for testing the classification developed with the Mamdani/Sugeno FIS and comparing the results are:

1. The Sugeno FIS is more flexible because it allows more parameters in the output. Since the output is a function of the inputs, it expresses a more explicit relation among them;
2. In computational terms, the Sugeno FIS is more effective because the complex defuzzification process of the Mamdani FIS is replaced with a weighted average;
3. Because of the structure of the Sugeno FIS rule outputs, it is more convenient for functional analysis than a Mamdani FIS is.

From the above-mentioned results, it seems that any Sugeno FIS is always more efficient than a Mamdani FIS. In conclusion, in this research only the "generic system level alarms" module is considered for performing the comparison.

3. ANFIS MODEL

The acronym ANFIS derives its name from adaptive neuro-fuzzy inference system. Using a given input/ output data set, the toolbox function ANFIS constructs a fuzzy inference system (FIS) whose membership function parameters are tuned (adjusted) using either a back propagation algorithm alone or in combination with the least squares type of method. This adjustment allows your fuzzy systems to learn from the data they are modeling. See [24]

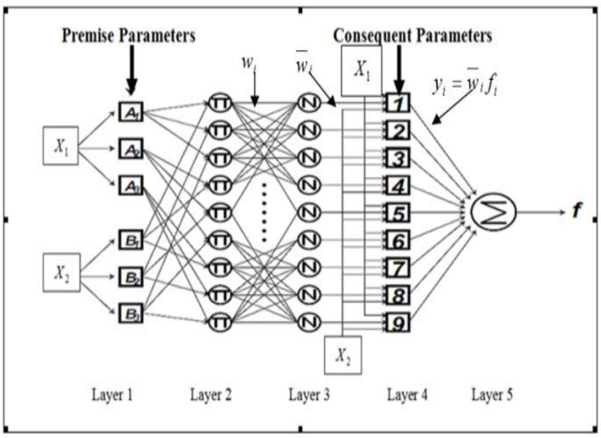

Fig. 1 Explain ANFIS Structure

The ANFIS approach defines a Takagi-Sugeno fuzzy inference system through a Neural Network approach by defining 5 layers:

- Layer 1: fuzzyfication of the input values due to MSFs -> membership degrees.

$$O_i^1 = \mu_{A_i}(x_1), \mu_{B_i}(x_2)$$

where X_1 and X_2 are the inputs.

- Layer 2: aggregation of membership degrees due to an appropriate t-norm applied in the premise parts.

$$O_i^2 = w_i = AND \quad rule(\mu_{A_i}(x_1), \mu_{B_i}(x_2))$$

- Layer 3: evaluation of the basis functions by normalization of aggregated membership degrees.

$$O_i^3 = \overline{w_i} = \frac{w_i}{w_1 + w_2 + \cdots + w_9}$$

- Layer 4: weighting of basis functions with linear (=> Takagi-Sugeno system) or constant (=> Sugeno system) consequent functions.

$$O_i^4 = y_i = \overline{w_i} f = \overline{w_i}(p_i x_1 + q_i x_2 + r_i)$$

- Layer 5: evaluation of output values by applying

$$O_i^5 = \sum_i \overline{w_i} f_i$$

4. APPLICATIONS OF FIS

4.1 Shows the Application of Mamdani FIS

Prices of fund in the Egyptian market are predicted using the Mamdani fuzzy model. It consists of one input Price levels. The system has one output that Market conditions. The prices are taken to be in the ranges of 450 to 2550. The researcher applied the method of Mamdani gbellmf, trying to find the best one for prediction. The input has nine membership functions as shown in Fig. (2). The output (Market conditions) is taken in values in range from 450 to 2550 and have nine Triangular membership functions shown in Fig. (3). The Rule base of Mamdani-type FIS is shown in Table (1). Finally, the comparison between the actual value and Mamdani gbellmf values is shown in Fig. (4). see [16]

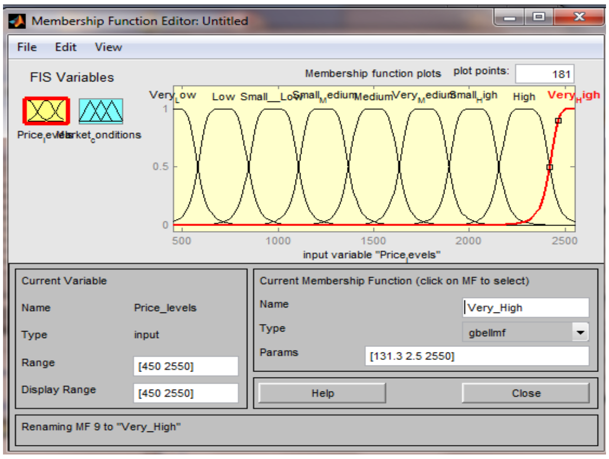

Fig. 2 Mamdani Bell membership function

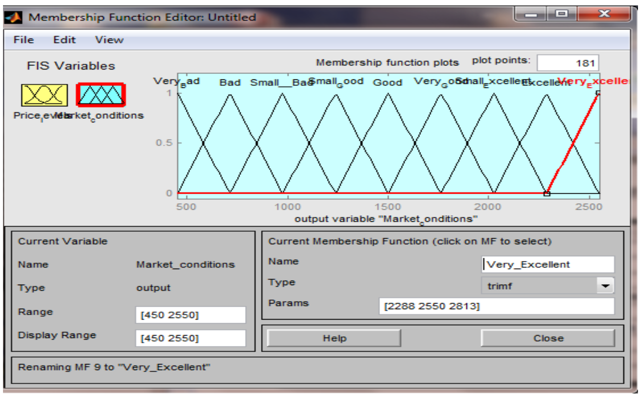

Fig. 3 Market conditions Triangular membership function.

Table 1: Rule base of Mamdani FIS

Rules	Price levels	Market conditions
Rule 1	Very Low	Very Bad
Rule 2	Low	Bad
Rule 3	Small Low	Small Bad
Rule 4	Small Medium	Small Good
Rule 5	Medium	Good
Rule 6	Very Medium	Very Good
Rule 7	Small High	Small Excellent
Rule 8	High	Excellent
Rule 9	Very High	Very Excellent

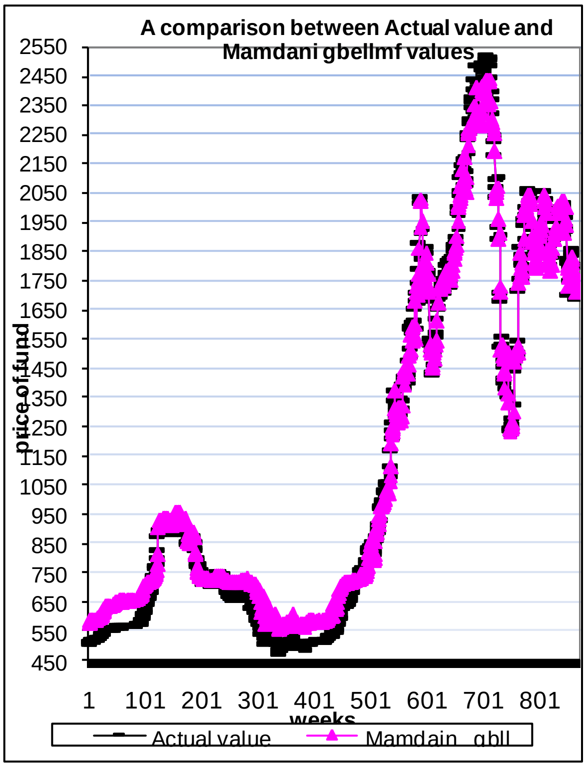

Fig. 4: showing comparison between Actual value and Mamdani gbellmf values.

4.2 Shows the Application of Sugeno FIS

Prices of fund in the Egyptian market are predicted using the Sugeno fuzzy model. It consists of one input Price levels. The system has one output: Market conditions. The prices are taken to be in ranges of 450 to 2550. The researcher applied the method of Sugeno gaussmf, trying to find the best one for prediction. The input has nine membership functions as shown in Fig. (5).The output (Market conditions) is taken in values in the range from 450 to 2550 and have nine Triangular membership functions shown in Fig. (6). The Rule base of Sugeno -type FIS is shown in Table (2). Finally, a comparison between the actual values and Sugeno gaussmf values is shown in Fig. (7). see [16]

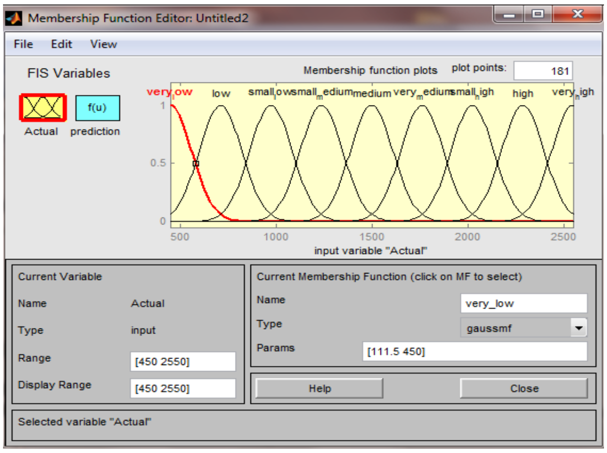

Fig. 5 Sugeno gaussmf

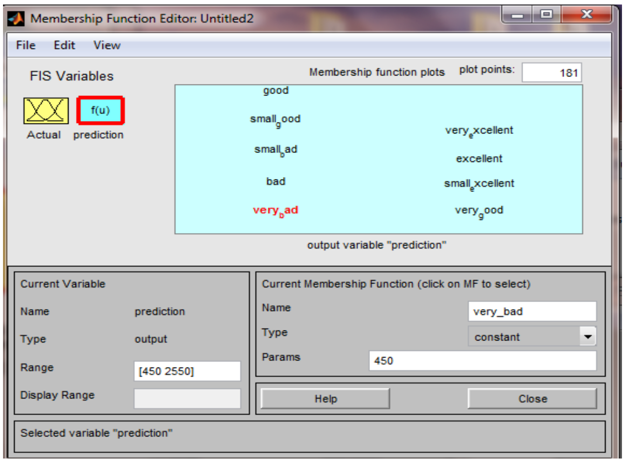

Fig. 6 The output Market conditions are taken in values in range from 450 to 2550

Table 2 : Market conditions membership functions

Market conditions	Constant value
Very Bad	450
Bad	700
Small Bad	900
Small Good	1300
Good	1500
Very Good	1750
Small Excellent	2000
Excellent	2250
Very Excellent	2550

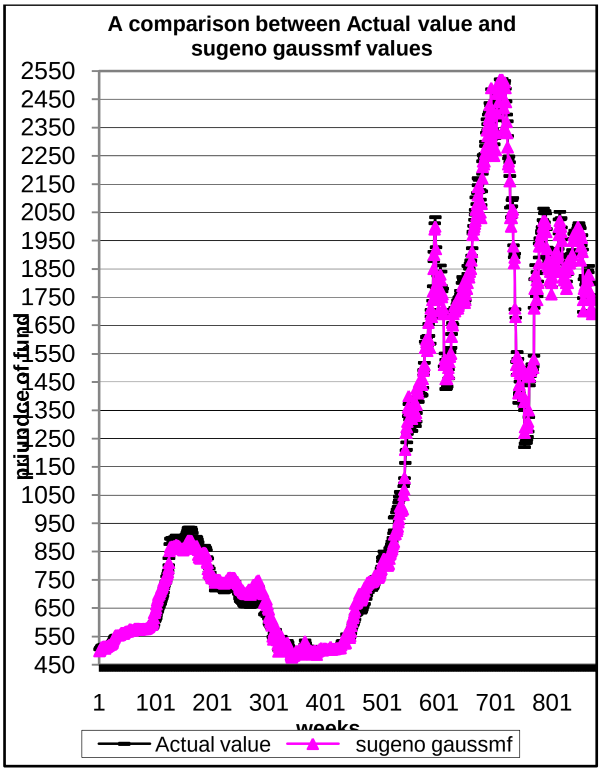

Fig. 7: showing comparison between Actual value and Sugeno gaussmf values.

4.3 Shows the Application of ANFIS Model

The researchers design a program by using MATLAB's programming to evaluate the ANFIS Model in the prediction. In addition to this, several attempts are conducted to reduce the rate of (RMSE) for the price of the fund. **First**, five membership functions and a hundred epochs were chosen, which resulted in (RMSE) **= 139.5.** In the **second** attempt, the number of membership functions was 10 and the number of epochs was 200, which resulted in (RMSE) = 110.5. In the **third** attempt, the membership functions was 15 and the number of epochs was 200, which resulted in (RMSE) = 175.6. In the **fourth** attempt, the number of membership functions was 20 and the number of epochs was 300, which resulted in (RMSE) = 12.05. In the **fifth** attempt, the number of membership functions was 20 and the number of epochs was 500, which resulted in (RMSE) = 84.95. It is noticed that the fourth attempt is the best one of the results since the measure (RMSE) = 12.05, which is the smallest one of them. The results of the fourth attempt were shown in Fig. 8 and Fig. 9.

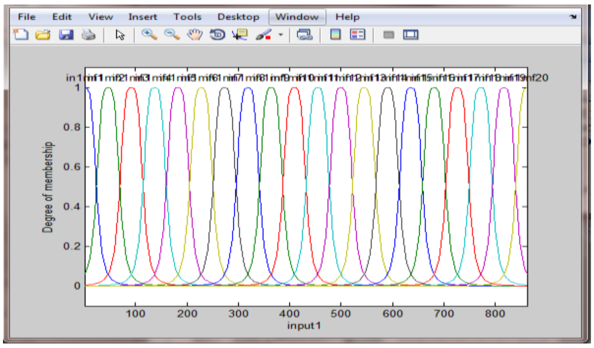

Fig. 8 Gaussian shape of the membership function

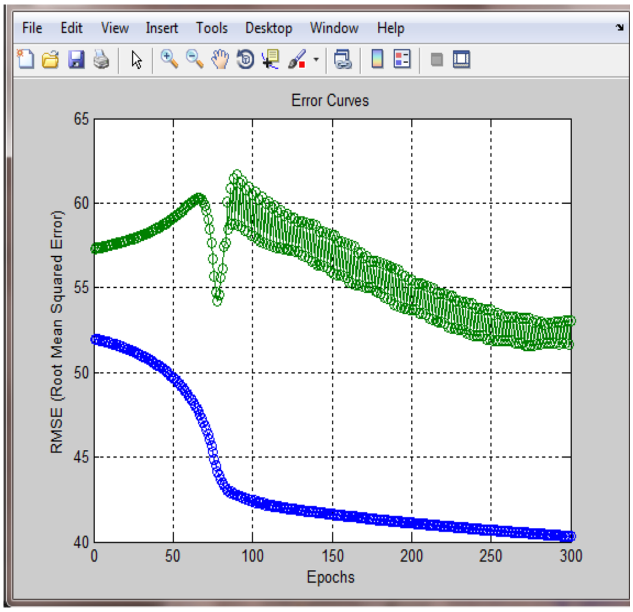

Fig. 9 (RMSE) Root Mean Squared Error of ANFIS Model

The program used and the process of prediction.

The program used was MATLAB which was used in the ANFIS model. The best results predicted were 1-862 price of fund. Actual values and ANFIS values related to the fund prediction were shown in Fig. 10.

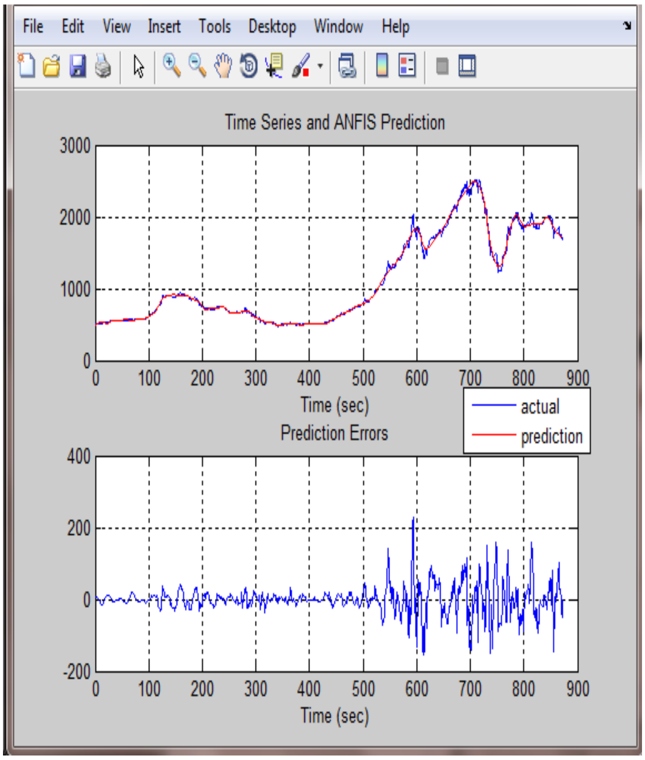

Fig. 10 time series and ANFIS prediction prices of fund per a week

5. RESULTS AND DISCUSSIONS

5.1 A comparison T-test between Actual values (μ_n) and predicted values of ANFIS, Mamdani and sugeno X_n which is based on (30, 100, 300, 500 and 862) weeks as sample sizes.

$$H_0 : \mu_n = X_n \quad against \qquad H_1 : \mu_n \neq X_n$$

- $\mu_n = X_n$: There is no difference between the means $P-value \succ 0.01$ It is not significant.
- $\mu_n \neq X_n$: There is difference between the means. $P-value \prec 0.01$ It is significant.

Table 3: A Comparison between the actual values (Arithmetic means μ_n), and prediction values for each of the methods of ANFIS, Mamdani and Sugeno (Arithmetic means X_n) by T-test.

Methods Actual X_n / values μ_n	ANFIS	Mamdani gbellmf	Sugeno gaussmf
Actual values n=30	P= 0.617	P= 0.000**	P= 0.262
Actual values n=100	P= 0.904	P= 0.000**	P= 0.185
Actual values n=300	P= 0.986	P= 0.000**	P=0.459
Actual values n=500	P= 0.985	P= 0.000**	P=0.935
Actual values n=862	P= 0.996	P=0.016*	P=0.970

**P≤ 0.01, high significant

*P≤ 0.05, significant

Referring to the result of Table (3), it should be noticed that:

The T-test of difference between actual values and predicted values of Mamdani method of (30, 100, 300, 500 and 862) weeks is significant at level P-values < 0.01 and 0.05. However, the T-test of difference between actual values and predicted values of both ANFIS and Sugeno methods of (100, 300, 500 and 862) weeks is non-significant at level P-values > 0.01 and 0.05.

5.2 Mean Absolute Error (MAE) for the methods of ANFIS, Mamdani and Sugeno which consist of 30, 100, 300, 500 and 862 weeks.

In order to be at P-values, this result can be achieved by using the Mean Absolute Error (MAE) measure as follows.

Table 4: Comparison between different methods based on MAE for the methods of ANFIS, Mamdani and sugeno

Methods / MAE	ANFIS	Mamdani	Sugeno
MAE n=30	8.2	70.9	4.7
MAE n=100	6.2	82. 9	10.2
MAE n=300	11.3	56.7	21.8
MAE n=500	10.1	61.9	33.8
MAE n=862	25.0	51.4	31.5

Referring to the result of Table V, it should be noticed that:

The researcher found that ANFIS model and Sugeno FIS are better than Mamdani FIS. But ANFIS model is the most efficient one of them.

Finally, the researchers believed ANFIS model is very good for forecasting the price of fund in the periods of severe economic fluctuations.

6. CONCLUSION

This paper has examined the performance of three types of Fuzzy logic Inference systems: ANFIS, Mamdani and Sugeno for predicting prices of Fund. It also confirms that a Sugeno FIS is always more efficient than a Mamdani FIS. All in all, the performance of ANFIS method is better than that of Sugeno and Mamdani for the same fuzzy technique.

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