

Comparison of Mamdani and Sugeno Fuzzy Inference Systems for prediction (with application to prices of Fund in Egypt)

Abstract:- This paper outlines the basic difference between the Mamdani fuzzy inference systems (FIS), Sugeno fuzzy inference systems (FIS) and the actual values. Fuzzy inference systems can be used for the prediction of prices of Fund, using Mamdani and Sugeno fuzzy models to predict weekly prices of Fund for the Egyptian Market. The application results indicate that Sugeno model for predicting prices of Fund is better than that of Mamdani. The results of the two fuzzy inference systems (FIS) are compared.

Key words: - Fuzzy Inference System (FIS), Fuzzy Logic, Mamdani FIS, Sugeno FIS, prices of Fund

I. Introduction

Due to living in an ever-changing economic environment, we see that this change happens in many periods measured by years, months, weeks and days. Sometimes we see phenomena in which the change may take place suddenly, such as the world economic crisis which happened in the past days and we are still suffering from this crisis till now. Thus, the importance of building models for forecasting lies in the expectation of such crises. Fuzzy logic is closer in spirit to human thinking and natural language than conventional logical systems. The Fuzzy Logic method is a relatively modern method. It depends on the obscurity logic which is one of the ways of logic.

Kisi (2013) compared two different fuzzy genetic methods and indicated that the Sugeno fuzzy genetic method was faster and had better accuracy than that of Mamdani in modeling daily evapotranspiration. **Kaur** (2012), showed that Sugeno results are relatively better than those of Mamdani for air conditioning system. **Guney** (2009) compared the performance of

¹ Professor of Mathematical Statistics, Institute of Statistical Studies and Research (ISSR), Cairo University, Egypt.

^B Professor of Statistics, Dept. of Statistics and Mathematics, Benha University, Egypt.

^C PHD student, Dept. of Statistics and Mathematics, Benha University, Egypt.

Mamdani and Sugeno methods for calculating the resonant frequency of rectangular microstrip antennas and concluded that the best result is obtained from the Sugeno FIS model trained by the least squares algorithm. For **Elamvazuthi** (2009), Mamdani method also achieved good results in Auto Zoom Function of a Digital Camera.

The researcher was able to apply Mamdani and Sugeno methods to find the best one for prediction. The rest of the paper is organized as follows: Section II gives the difference between Mamdani and Sugeno FIS, Section III shows the application of Mamdani FIS, Section IV shows the application of Sugeno FIS, Section V gives results and discussions, and section VI conclusions.

II. Used Abbreviations.

Fuzzy inference systems (FIS).

Triangular Membership Function (trimf).

Trapezoidal Membership Function (trapmf).

Gaussian Membership Function (gaussmf).

Gbell membership function (gbellmf)

Mean Absolute Error (MAE)

III. Mamdani FIS VS. Sugeno FIS

Mamdani method is widely accepted for capturing expert knowledge. It allows us to describe the expertise in a more intuitive, human-like manner. It is similar to the Mamdani method in many respects. The first two parts of the fuzzy inference process, fuzzifying the inputs and applying the fuzzy operator, are exactly the same. The main difference between Mamdani and Sugeno is that the Sugeno output membership functions are either linear or constant [1].

Sugeno method is a more compact and computationally efficient representation than a Mamdani system; the Sugeno system lends itself to the use of adaptive techniques for constructing fuzzy models. These adaptive techniques can be used to customize the membership functions so that the fuzzy system best models the data. The following are some final considerations about the two different methods.

The Advantages of the Sugeno Method are:

It is computationally efficient. It works well with linear techniques (e.g., PID control) as well as with optimization and adaptive techniques. Moreover, it has guaranteed continuity of the output surface and it is well suited to mathematical analysis.

The Advantages of the Mamdani Method are:

It is intuitive, has widespread acceptance and is well suited to human input. Mamdani FIS is less flexible in system design in comparison to Sugeno FIS as the latter can be integrated with ANFIS tool to optimize the outputs [6].

IV. Application of Mamdani FIS.

Prices of fund in the Egyptian market are predicted using Mamdani 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 methods of Mamdani Trimf, Mamdani gbellmf, Mamdani gaussmf and Mamdani Trapmf, trying to find the best one for prediction. The input has nine membership functions as shown in Figs: 1, 2, 3 and 4. The output (Market conditions) is taken in values ranging from 450 to 2550 and has nine triangular membership functions shown in Fig. 5.

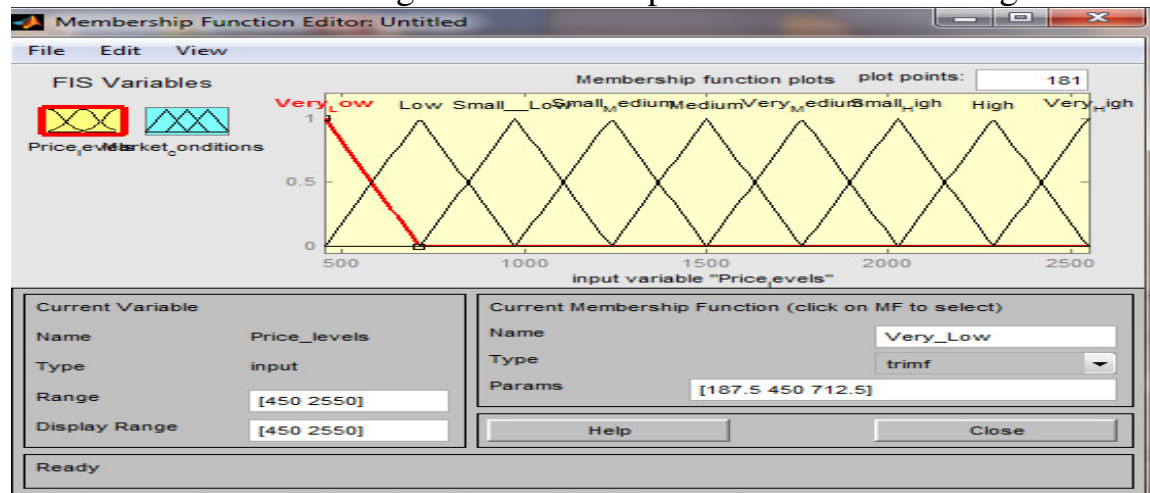


Fig.1. Mamdani Triangular membership function

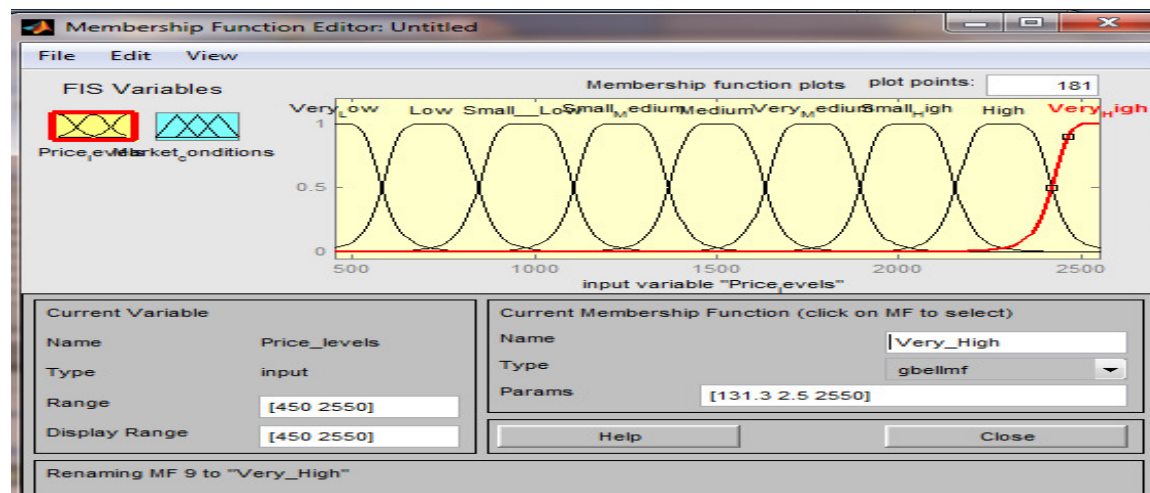


Fig.2. Mamdani Gbell membership function

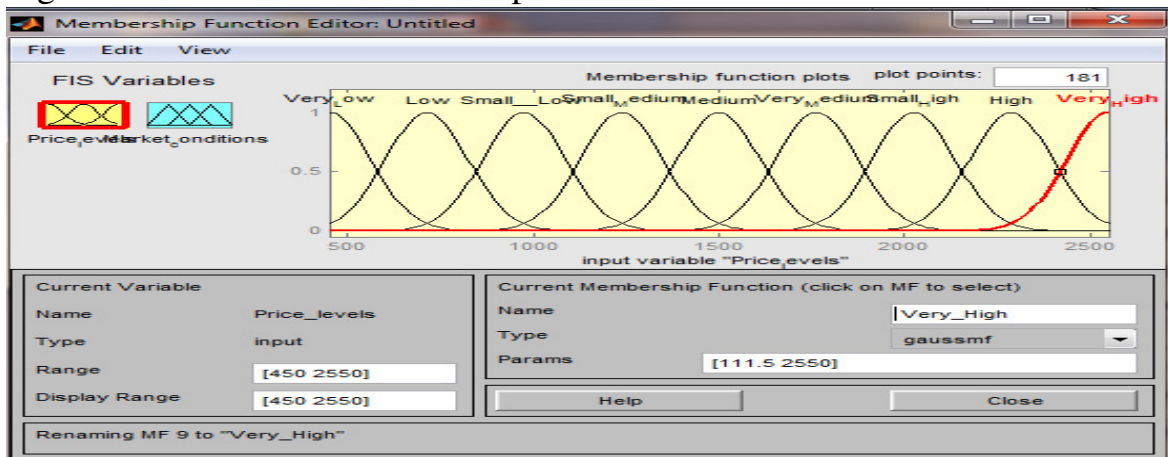


Fig.3. Mamdani Gaussian membership function

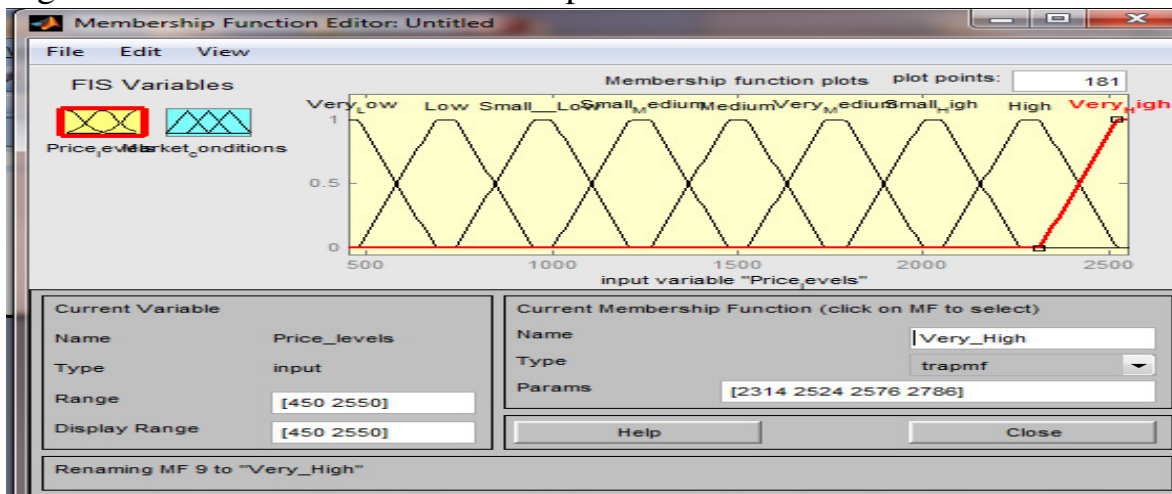


Fig.4. Mamdani Trapezoidal membership function

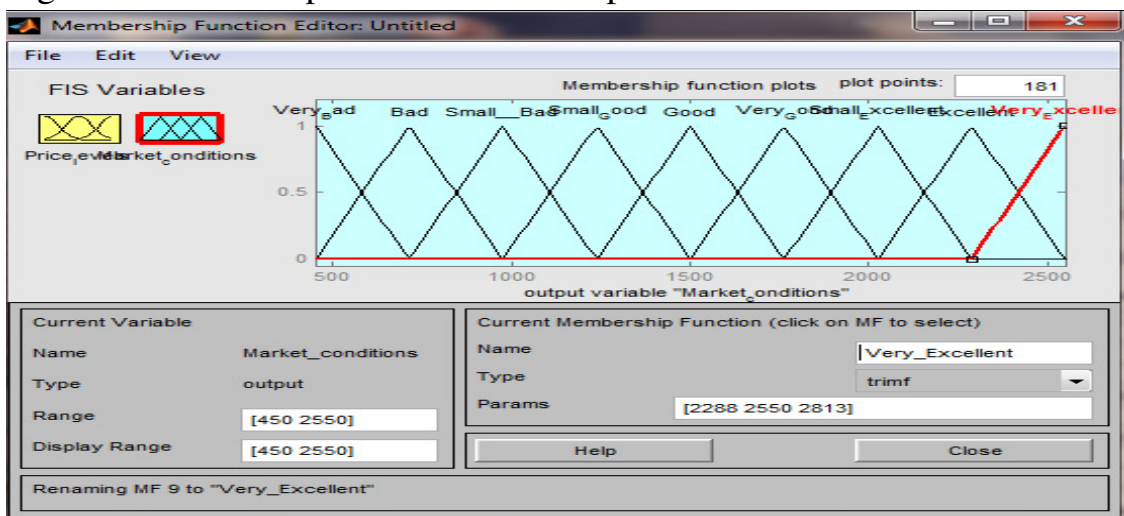


Fig.5. Market conditions Triangular membership function

Table (1): Rule base of Mamdani FIS

Rules	Price levels	Market conditions
R1	Very Low	Very Bad
R2	Low	Bad
R3	Small Low	Small Bad
R4	Small Medium	Small Good
R5	Medium	Good
R6	Very Medium	Very Good
R7	Small High	Small Excellent
R8	High	Excellent
R9	Very High	Very Excellent

In table (2), the Prediction values of Mamdani methods are calculated.

Table (2)

No.	Weeks	Actual values	Mamdani trimf	Mamdani gbellmf	Mamdani gaussmf	Mamdani trapmf
1	29/06/1995	503.52	614	575	603	589
2	06/07/1995	505.5	616	576	605	593
--	-----	-----	-----	-----	-----	-----
861	08/12/2011	1826	1800	1780	1790	1770
862	15/12/2011	1794	1810	1780	1800	1790

V. Application of Sugeno FIS

Prices of fund are predicted using Sugeno model for Egyptian fund data. The initial steps are the same as those of Mamdani model. The system has one output: Market conditions. The prices are taken to be in ranges of 450 to 2550. The researcher applied the methods of Sugeno Trimf, Sugeno gbellmf, Sugeno gaussmf and Sugeno Trapmf, trying to find the best one for prediction. The output (Market conditions) is taken in values ranging from 450 to 2550 and has nine membership functions shown. The rule base for Sugeno FIS is the same as that of Mamdani FIS as shown in Table 1.

Table (3). Market conditions membership functions

Market conditions	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

In table (4) the Prediction values of Sugeno methods are calculated.

No.	Weeks	Actual values	Sugeno trimf	Sugeno gbellmf	Sugeno gaussmf	Sugeno trapmf
1	29/06/1995	503.52	511	475	498	488
2	06/07/1995	505.5	513	476	500	491
--	-----	-----	-----	-----	-----	-----
861	08/12/2011	1826	1810	1770	1790	1790
862	15/12/2011	1794	1780	1760	1770	1760

- A comparison T-test between Actual values and predicted values of Mamdani methods, which is based on (n= 30, 100, 300, 500 and 862) weeks as sample sizes.

$$H_0 : P_0 = P_n \text{ against } H_1 : P_0 \neq P_n$$

- $P_0 = P_n$: There is no difference between the means. $P > 0.01$ It is not significant.
- $P_0 \neq P_n$: There is difference between the means. $P < 0.01$ It is significant.

Table (5): A Comparison between the actual values and predicted values for each of the methods of Mamdani by T-test.

Methods Actual values	Mamdani Trimf	Mamdani gbellmf	Mamdani gaussmf	Mamdani Trapmf
Actual values n=30	P= 0.000**	P= 0.000**	P= 0.000**	P= 0.000**
Actual values n=100	P= 0.000**	P= 0.000**	P= 0.000**	P= 0.000**
Actual values n=300	P= 0.000**	P= 0.000**	P= 0.000**	P= 0.000**
Actual values n=500	P= 0.000**	P= 0.000**	P= 0.000**	P= 0.000**
Actual values n=862	P=0.282	P=0.360	P=0.257	P=0.309

* $P \leq 0.01$, high significant

Table (6): A Comparison between the actual values and predicted values for each of the methods of Sugeno by T-test.

Methods Actual Values P_0	sugeno Trimf P_1	sugeno gbellmf P_2	sugeno gaussmf P_3	sugeno Trapmf P_4
Actual values n=30	P1= 0.005**	P2= 0.000**	P3= 0.262	P4= 0.058
Actual values n=100	P1= 0.001**	P2= 0.002**	P3= 0.185	P4= 0.170
Actual values n=300	P=0.389	P=0.386	P=0.459	P=0.332
Actual values n=500	P=0.219	P=0.486	P=0.935	P=0.428
Actual values n=872	P=0.848	P=0.941	P=0.970	P=0.944

* $0.01 \geq P$, high significant

- **Mean Absolute Error (MAE) for the methods of Mamdani and Sugeno prediction set (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 (7): Comparison between different methods based on **MAE** for the Mamdani.

MAE \ Methods	Mamdani Trimf	Mamdani gbellmf	Mamdani gaussmf	Mamdani Trapmf
MAE n=30	110.836	70.901	98.988	95.783
MAE n=100	103.864	82.89	97.893	97.543
MAE n=300	64.0354	56.696	62.49	61.408
MAE n=500	78.2881	61.965	73.854	69.958
MAE n=872	80.9702	51.427	58.548	82.148

Table (8): Comparison between different methods based on **MAE** for the methods Sugeno.

MAE \ Methods	sugeno Trimf	sugeno gbellmf	sugeno gaussmf	sugeno Trapmf
MAE n=30	10.715	32.524	4.7489	8.9631
MAE n=100	14.894	23.707	10.233	11.532
MAE n=300	28.703	35.761	21.824	31.011
MAE n=500	37.837	41.614	33.834	37.617
MAE n=872	36.944	40.855	31.552	39.563

VI. Results and Conclusion

- 1) From table (5) all four methods show a significant difference between the actual values and predicted values for all n except for n is large (near 1000 or more).
- 2) Table (6) shows that sugeno methods are sensitive to the type of fuzzy function and give better results (using Sugeno gaussmf).
- 3) Comparing the four proposed method using MAE measure, it is found that Mamdani gbellmf gives the best results.

In general, the performance of sugeno method is better than that of Mamdani for the same fuzzy technique.

Also the guassan fuzzy membership function usually gives better results than other functions.

Reference

- 1- **Elamvazuthi I., Vasant P. & Webb J. (2009)**, “The Application of Mamdani Fuzzy Model for Auto Zoom Function of a Digital Camera”, International Journal of Computer Science and Information Security, Vol. (6), p 244-249.
- 2- **Guney K. & Sarikaya N. (2009)**, “Comparison of Mamdani and Sugeno fuzzy inference system models for resonant frequency calculation of Rectangular Microstrip Antennas” Progress In Electromagnetics Research B, Vol. (12), p 81–104.
- 3- **Kaur A. & Kaur A. (2012)** “Comparison of Mamdani-Type and Sugeno-Type Fuzzy Inference Systems for Air Conditioning System”, International Journal of Soft Computing and Engineering (IJSCE) Vol.(2), p 323-325.
- 4- **Kisi O. (2013)**, “Applicability of Mamdani and Sugeno fuzzy genetic approaches for modeling reference evapotranspiration” Journal of Hydrology, Vol. (504), P 160–170
- 5- **Negnevitsky M., (2005)** “Artificial Intelligence A Guide to Intelligent Systems” Pearson Education Limited, England.