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# ORGANIZATION: COMPARISON MAMDANI FUZZY LOGIC vs SUGENO

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**Rezumat.** Dezvoltarea economiei mondiale într-un ritm extrem de rapid urmată de criză economică a impus orientarea către analize, atât la nivel macroeconomic cât și microeconomic, ale indicatorilor economici aflați în interdependență în spațiul tridimensional prin vizualizarea de rapoarte unificate cât și și combinații ale datelor de intrare unele față de altele. Aceste analize utilizează în prezent noțiunea (conceptul) de fuzzy logic pentru a descrie cât mai apropiat de realitate fenomenele sau procesele care sunt extrem de instabile. Astfel multitudinea factorilor de intrare este influențată de feedback-ul organizațiilor.

**Abstract.** Developing world-wide economy in an extremely fast rate of economic crisis followed by analysis required orientation at both the macro and micro economic indicators are interdependent in three-dimensional space by viewing reports and unified and combinations of input data to each other. These analyzes currently use concept (concept) of fuzzy logic to describe how close to reality phenomena or processes that are highly unstable. So many factors input is influenced by feedback organizations.

**Keywords:** fuzzy logic, fuzzy rules, mamdani, sugeno, membership functions

## 1. Introduction

The current research on database analysis of an organization is aimed to identifying the components that are vaguely defined and uncertain or unstable.

This product's life cycle and represented the material and technological flow, product use, distribution, recycling mode (end of life) were analyzed [1, 2] and this complex process modeling and coding was done with a soft powerful.

Integrated planning and scheduling systems encountered in industry are modeled using fuzzy sets theory (FST), which increased the interest of corporations to use these methods with powerful software to make decisions on performance evaluation of various departments and allocate/reallocate resources [3].

Type multi-criteria decisions are currently the most valuable because it covers an extensive range of input data analysis because of the flexibility is very important in various applications whatever their nature [4]. Multiple criteria decision making (MCDM) approached so far [5] techniques, including multi-objective decision making (MODM), are shown in their implementation in organizations.

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By his decisions, the manager must have open approach to predict the possible meaning of action of input / output factors' action connected by feedback, so that to obtain a unique solution [6]. Unique solution, which is the correlation between cause and effect has practical implications by supporting the organization's decision-making system [7].

## 2. The current state

### 2.1. Uncertainties about the price and the product

Optimizing a company's presence on the market, domestic and international, depends on the ability to predict trends in its portfolio of clients on the acquisition and quality of products and the range of prices.

Inaccurate estimates lead to risks of supply of raw materials at high prices and large stocks, so the increase in the stock of products. Dangerous situations are the products of category *Question marks* or *Dogs* [8].

Wrong predictions about the transition period of a product can lead to cannibalization effect (old and new competing products) [9].

The dynamic modeling of system based on market conditions and the dynamic interactions between the product and the launching chosen strategy elements lead to good results but are limited by time of transition and cost evaluation [10].

A special interest in terms of uncertainty is the ensemble product/price/climatic variations in ambient temperature [11, 12]. Temperature changes, for instance, a range of 14-30 days, can cause extremely variations of prices and stocks (eg. agricultural products), may not be predictable. For some products these variations in climate temperature, even for a few days can change the characteristics of the market by passing the opposite. So, in HVAC equipments price range if temperatures increase for 3…5 days (e.g. $35^0$C day / night $23^0$C) lead to exponential growth in sales, then temperatures decrease for 2…3 days, the sales return to their linear trend.

### 2.2. Discontinuity in the supply chain

These discontinuities must be analyzed from two points of view:

a) Discontinuity in of supply from suppliers;
b) Discontinuity in distribution to customers;

These discontinuities arise when a market demand exceeds supply in the case of success, the product is at end of life, but when a new product is introduce on the market by rapid distribution to customers in the hope that product will penetrate the market. Fast delivery of a product's success is not always in the market [13].

A decision-making model to solve the problem of discontinuity old products - new product development, was based on the fuzzy inference systems (FIS) [14], the elements are too vague / uncertain to be evaluated numerically.

If recycling products discontinuity occurrence of very complex because uncertainties include [15]:

a) the supply and distribution of products used;
b) the quality and quantity of components unknown products used;

### 2.3. Consulting and maintenance

Consulting activity that provides an intermediary product providers and beneficiaries is necessary to obtain an overview of the real investment from the design phase and ending with the commissioning phase (PIF). Consultancy services are provided by specialists (commercial technical representative - RTC) with extensive training, able to meet all circumstances, the technically required by the projects beneficiaries.

Maintenance, as the system plays a key role in reducing costs, minimizing equipment downtime, improves quality, increases productivity and supplies of reliable equipment all competing to achieve organizational goals and objectives [16].

In the literature are presented following types:

- corrective maintenance - takes place when equipment malfunctions occurred;
- time-based preventive maintenance - is planned and carried out periodically [17];
- condition-based maintenance - monitoring equipment and sensors based on the appearance of the first symptoms are performing the procedure [17];
- predictive maintenance - by analyzing databases of different parameters that can be monitored weather trend and predict performance degradation defects;

## 3. The concept of Fuzzy Logic Systems (FSL)

Based on research conducted by Jan Lukasiewicz in 1920 on three-valued logic was generalized in 1930 in infinitely-many-valued [18] Askar Lotfi Zadeh in 1965 (professor at the University of California, Berkeley) introduced the term fuzzy logic fuzzy set theory to explain [19].

Fuzzy systems are considered a particular case of expert systems that provide a flexible method for the treatment of uncertainty. Fuzzy logic continues working with a wide range of values in [0, 1], where 0 is considered complete falsity and one complete truth, so working with the degree of membership of the object from the set.

Fuzzy set theory transpose human judgments qualitative quantitative numerical expressions by simultaneous numerical data and lexical knowledge and the fact that working with values in the range [0, 1] there are many extreme possibilities leading to different transformations. So we can say that approximate fuzzy logic processes information in a systematic way is suitable for modeling complex nonlinear systems and control.

Characterization is done by fuzzy quantities linguistic forms that allows to clearly define the rules which will form the basis of fuzzy system's rules. The terminology used to formulate linguistic information is realized by linguistic variables (LV) and linguistic terms (LT) related applications [20].

### 3.1. Analytical characteristics of fuzzy sets

Let X be a crisp set whose elements we want to consider using fuzzy techniques [21]. Then:

$$A = \{(x, \varphi_A(x)) \mid x \in X\} \tag{1}$$

defines a fuzzy set of X where $\varphi_A$ is the function of membership to set *A* relative to $A \subseteq X$ iar $\varphi_A(x)$ represents the degree of membership of *x* in fuzzy *A*. Usually $\varphi_A(x) \in [0,1]$. The set X is called the **universe of discourse**.

Analytical characterization of fuzzy sets is performed with the following sizes:

a) **Support** the set *A* note $Supp(A)$ is cut strict level 0 of the set *A*:

$$Supp(A) = \{x \in X \mid \varphi_A(x) = 1\} \tag{2}$$

b) It's called the **threshold cut α** or **α-cut** the set crisp:

$$[\varphi]_\alpha = \{x \in X \mid \varphi(x) \geq \alpha\} \tag{3}$$

If the inequality is strict is said $\alpha - cut$ type is hard and will be noted $[\varphi]_{+\alpha}$.

c) The **kernel** set *A* noted $Ker(A)$ cut is 1 of the set threshold:

$$Ker(A) = \{x \in X \mid \varphi_A(x) \geq 1\} \tag{4}$$

d) **Height** set *A* noted $h(A)$ represents the highest value taken by of membership function:

$$h(A) = \sup\{\varphi_A(x) \mid x \in X\} \tag{5}$$

e) **Frontier** set *A* noted $Fr(A)$ is the set of elements that have crisp of membership degree intermediate between 0 and 1:

$$Fr(A) = \{x \in X \mid \varphi_A(x) \in (0,1)\} \tag{6}$$

- fuzzy set A is called **normal** or normalized if:

$$h(A) = \sup\{\varphi_A(x) \mid x \in X\} = 1 \tag{7}$$

and **subnormal** if:

$$h(A) = \sup\{\varphi_A(x) \mid x \in X\} < 1 \tag{8}$$

- fuzzy sets is called **zero** on the set of basic *X* if:

$$\varphi_A(x) = 0, \forall x \in X \tag{9}$$

- fuzzy set is called **universal** basic set *X* if:

$$\varphi_A(x) = 1, \forall x \in X \tag{10}$$

### 3.2. Fuzzy numbers

A fuzzy number *A* is a fuzzy subset of the real numbers' set with a convex and continuous of membership function with bounded support.

A fuzzy number A is called **triangular fuzzy number** with center *c*, width left $\alpha > 0$, the width of the right $\beta > 0$, if of membership function has the form:

$$\varphi_A(x) = \begin{cases} 1 - \dfrac{c-x}{\alpha}, c - \alpha \le x \le c \\ 1 - \dfrac{x-c}{\beta}, c < x \le c + \beta \\ 0, altfel \end{cases} \tag{11}$$

or using the **min** and **max** functions:

$$\varphi_A(x, c, \alpha, \beta) = \max\left( \min\left( \frac{c - \alpha + x}{\alpha}, \frac{c + \beta - x}{\beta} \right), 0 \right) \tag{12}$$

Fuzzy number is notated $A = (c, d, \alpha, \beta)$ with $\text{supp}(A) = (c - \alpha, d + \beta)$.

The significance of this fuzzy set with center c is "*x is approximately equal to c*".

A fuzzy number A is called **trapezoidal fuzzy number** with tolerance range $[c, d]$, the width of the left $\alpha > 0$, the width of the right $\beta > 0$, if it has the following function of membership:

$$\varphi_A(x) = \begin{cases} 1 - \dfrac{c-x}{\alpha}, c - \alpha \le x \le c \\ 1, c < x \le d \\ 1 - \dfrac{x-d}{\beta}, d < x \le d + \beta \\ 0, altfel \end{cases} \tag{13}$$

or using the **min** and **max** functions:

$$\varphi_A(x, c, d, \alpha, \beta) = \max\left( \min\left( \frac{c - \alpha + x}{\alpha}, 1, \frac{d + \beta - x}{\beta} \right), 0 \right) \tag{14}$$

Using the notation of fuzzy number $A=(c,d,\alpha,\beta)$ with $\text{supp}(A)=(c-\alpha,d+\beta)$, the significance of this fuzzy tolerance interval is "*x is approximately between c and d*".

**Gaussian membership function** is defined through two parameters $\{c,\sigma\}$ thus:

$$\varphi_A(x,c,\sigma)=e^{-\frac{1}{2}\left(\frac{x-c}{\sigma}\right)^2} \tag{15}$$

The parameter *c* is called the membership function center, and $\sigma$ width determines the membership function.

**Bell membership function** is defined by three parameters real $\{a,b,c\}$ thus:

$$\varphi_A(x,a,b,c)=\frac{1}{1+\left|\frac{x-c}{a}\right|^{2\cdot b}} \tag{16}$$

where *b* is a positive real parameter. This type of membership function is a generalization of Cauchy distribution used in probability theory.

Triangular and trapezoidal functions are generated based on the piecewise linear functions; sigmoidal functions and the bell are generated either on the basis of sigmoidal function or functions based on polynomial (quadratic or cubic) [22].

### 3.3. Basic components of information structure fuzzy logic

**I. Fuzzification block** is the input of information, transforming their role as linguistic variables, the linguistic terms and membership functions of a crisp value. This information is compared with the premises fuzzy rules like "IF ...THEN ..." contained in the rules and inference mechanism used to activate and their application.

**II. Block rule base** contains a set of rules like "IF ... THEN ..." set of expert and fuzzy variables defined on entry and exit. Base fuzzy logic rules they match the description language.

**III. Inference mechanisms** are control strategies or techniques search that queries the knowledge base to draw conclusions [23]. The inference rules manipulate symbols by selecting, matching symbols facts and then setting new facts. This process continues until the chain is reached for a particular purpose.
The most common methods of inference are:

a) **chaining back** - is a process led by a goal in the order they appear in the knowledge base;
b) **forward chaining** - is a data driven process. The user must make available data system before the start of inference. Inference mechanism seeks to establish the facts as they appear in the database until it achieved its goal;

**IV. Defuzzification block** ensures that result in decision block, a fuzzy value is converted into an actual physical value that will transmit process/actuator.

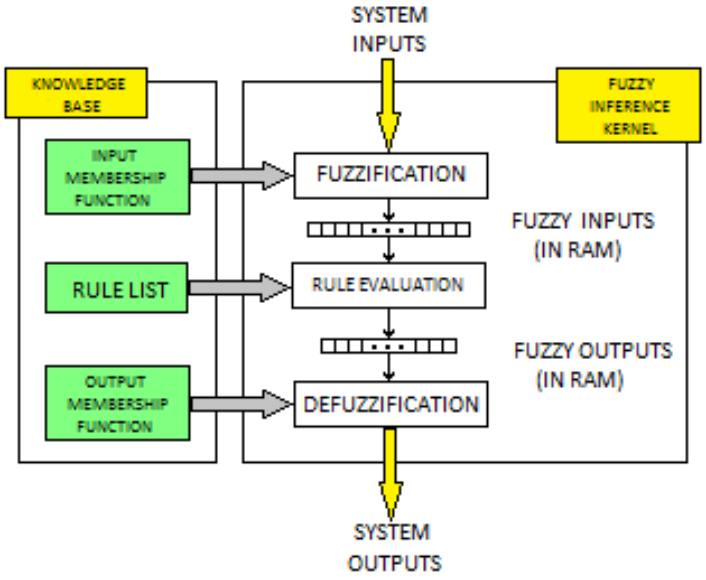



**Fig. 1** Diagrama blocurilor sistemului fuzzy logic [24]

Fuzzification/defuzzification repetitive cycles are not recommended because information is lost, that leading to the reduction potential of fuzzy logic [25]. Information loss is achieved by repeated transformation of input data that are numbers, the linguistic variables.

To overcome this inconvenience in [26] is proposed a method for efficient data recovery blocks hiding this information.

Because the models are not always accurate achieved is needed to ensure robustness in order to keep certain property in the event of variations between the real system and the model used. Robustness depends on the properties of triangular norm chosen. A rule which has the property of absorbing (**min-max**) is more robust than a rule that does not have this property (**prod-sum**).

Thus it is proposed to improve the robustness of systems defined neutrosophic logic inference neutrosophic [27].

### 3.4. Defuzzification methods

**Mamdani type defuzzification methods** [28]**:**

1. *centroid of area COA (center of gravity)*

This method returns an output defuzzification by calculating the center of gravity of the area delimited by aggregating the consequences of such fuzzy set:

$$y_{COA} = \frac{\int_v y \cdot \mu_B(y) \cdot dy}{\int_v \mu_B(y) \cdot dy} \tag{17}$$

*2. bisector of area BOA*

The vertical line corresponds BOA output generated by dividing the aggregate fuzzy sets in two subregions of equal area. This can be expressed as:

$$\int_{\alpha}^{y_{BOA}} \mu_B(y) \cdot dy = \int_{y_{BOA}}^{\beta} \mu_B(y) \cdot dy \tag{18}$$

where $\alpha = \min\{v | v \in V\}, \beta = \max\{v | v \in V\}$. The value resulting from this method is sometimes identical to that generated by the COA.

*COA* and *BOA* is used in control applications because it does not produce jumps in control surface.

*3. smallest of maximum SOM*

This method generates a clear output by taking the lowest value to provide the maximum degree of membership fuzzy set aggregate.

$$y_{SOM} = \min\{y | \mu_B(y) = \max(\mu_B(y))\} \tag{19}$$

*4. largest of maximum LOM*

This method generates a clear exit by taking the highest value to provide the maximum degree of membership fuzzy set aggregate.

$$y_{LOM} = \max\{y | \mu_B(y) = \max(\mu_B(y))\} \tag{20}$$

*5. mean of maximum MOM*

In this defuzzification, the maximum average output is taken as a clear.

$$y_{MOM} = \frac{y_{SOM} + y_{LOM}}{2} \tag{21}$$

*MOM, LOM, SOM* is used in applications of decision as it may cause jumps in the control area. The situation most advantageous method of execution occurs when the element presents a finite number of strong positions that can be associated with linguistic terms of "singleton" of the output quantity [30].

**Takagi-Sugeno methods type defuzzification:**

*a) weighted average WA*

This method of defuzzification output generates the final result for a Sugeno FIS weighting method centers of gravity of individual surfaces.

$$y_{WA} = \frac{\sum_{i=1}^{M} w_i \cdot y_i}{\sum_{i=1}^{M} w_i} \tag{22}$$

*b) weighted sum WS*

To reduce calculation *WA, WS* method only needs the rule weighted sum of outputs.

$$y_{WS} = \sum_{i=1}^{M} w_i \cdot y_i \tag{23}$$

## 4. Case Study

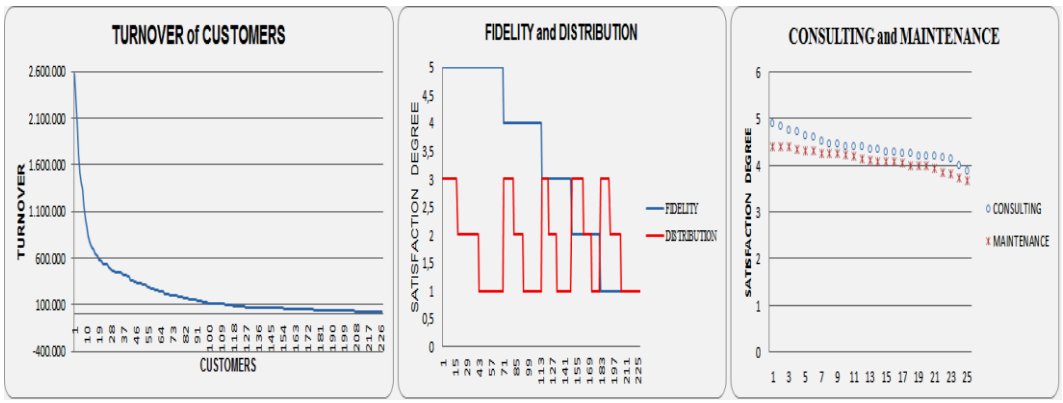
In organization's economic indicators study the aim is unified information results interpretation.

Unified analysis of information to be presented in this case study is the first stage of a complex study aimed final analysis in 3D space and time and how to assemble the final results (**simulator final results - SRF**) for: create an accurate representation of **States Past, Present and Future** (STPV) using fuzzy logic to understand the behavior of variables to reach the target [29]**.**

The study was conducted using the database of the SC Black Sea Suppliers SRL, Pitesti, Arges County branch, distribution carried out in Teleorman and Olt counties.

A number of 228 companies were selected for analysis from three countries (Fig. 2 b.) With a turnover in 2009-2013 (5 years), ranging from 20.000 to 2.600.000 RON (Fig. 2.) and between 4.000-520.000 RON/year [30].

The variables of input were also considered: fidelity (Fig. 2 b), consulting and maintenance (Fig. 2 c.)




a. b. c.

**Fig. 2 Graphical representation of input variables**

They were introduced the same data input and analysis rules for both Mamdani and Sugeno type. FIS input variables (for the period of 5 years), are shown in Fig. 3 and Fig. 4.

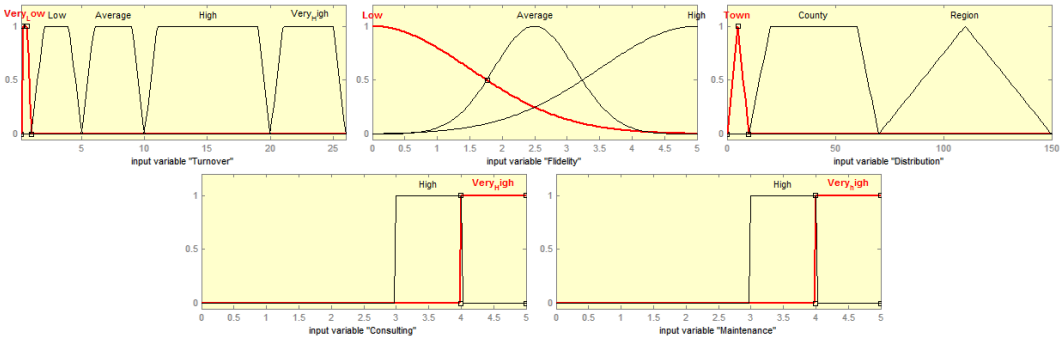



**Fig. 3** FIS input variables for Mamdani and Sugeno

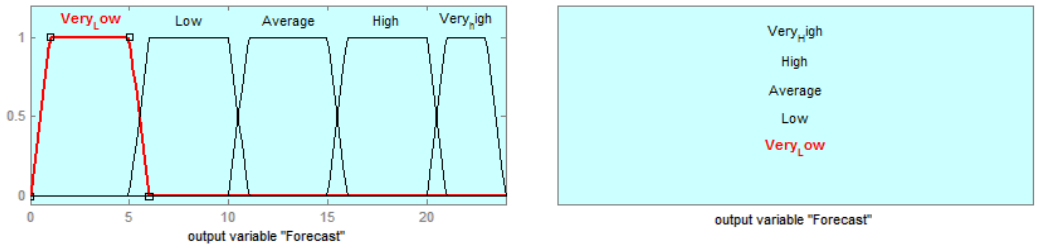


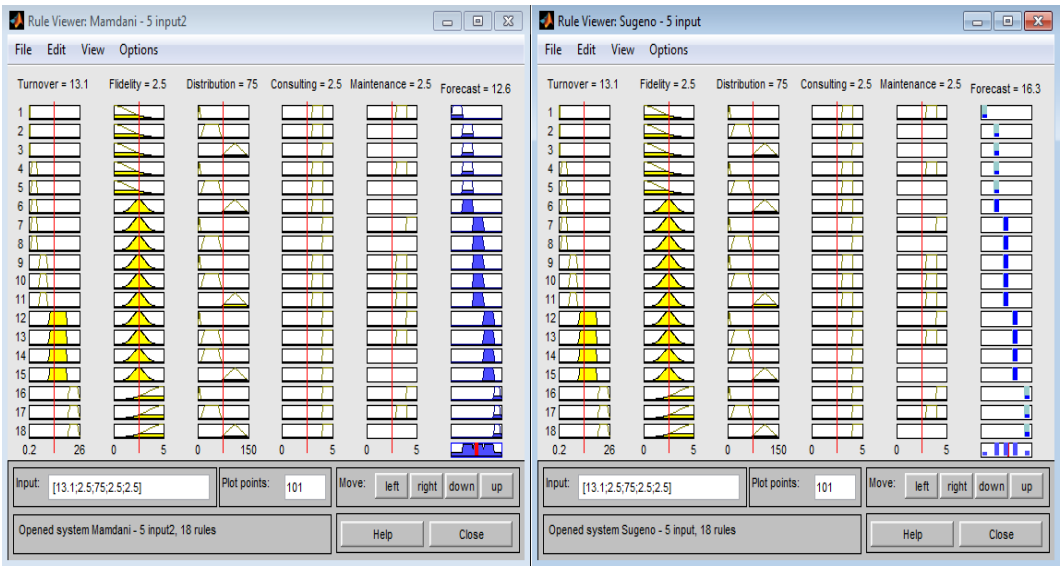

**Fig. 4** FIS output variables

a. Mamdani b. Sugeno

**Table 1** Mamdani and Sugeno rules established for

| | | |
|---|---|---|
| 1 1 1 2 2, 1 (1): 2 | 2 2 1 1 1, 3 (1): 2 | 4 2 2 1 2, 4 (1): 2 |
| 1 1 2 2 0, 2 (1): 2 | 2 2 2 1 0, 3 (1): 2 | 4 2 2 1 0, 4 (1): 2 |
| 1 1 3 1 0, 2 (1): 2 | 3 2 1 2 2, 3 (1): 2 | 4 2 3 1 0, 4 (1): 2 |
| 2 1 1 2 2, 2 (1): 2 | 3 2 2 2 2, 3 (1): 2 | 5 3 1 1 1, 5 (1): 2 |
| 2 1 2 2 0, 2 (1): 2 | 3 2 3 2 2, 3 (1): 2 | 5 3 2 1 2, 5 (1): 2 |
| 2 2 3 2 0, 2 (1): 2 | 4 2 1 1 1, 4 (1): 2 | 5 3 3 1 0, 5 (1): 2 |

After running the FIS for the same input variables they were obtained results shown in Fig.5 and Fig.6 Mamdani FIS for the FIS Sugeno.

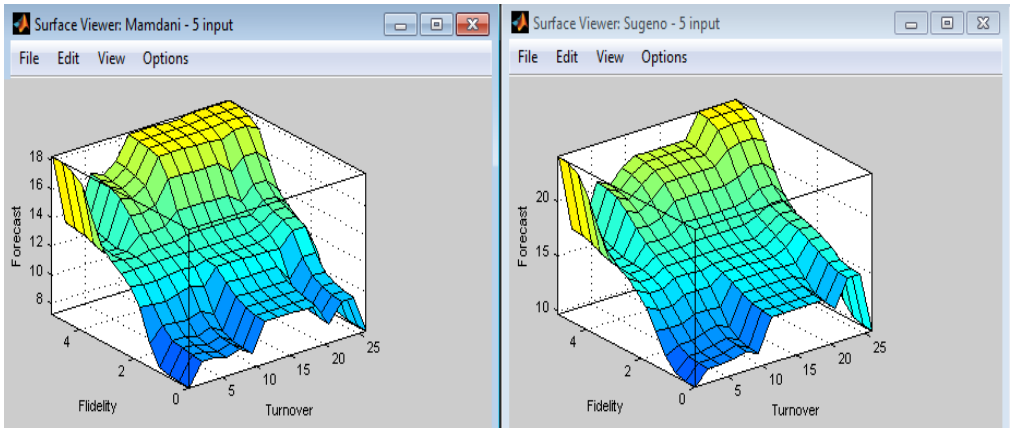



a. Mamdani b. Sugeno

**Fig. 5** Diagrams 5 inputs and one output FIS.

From the results of the two types FIS is observed that the method Sugeno (Fig. 5) to Mamdani method (Fig. 6) has a more restricted ranges forecast. So the disadvantage of this method is that predicts the beginning / end of the outcome and it intervenes rotation interval (ramp left / right).

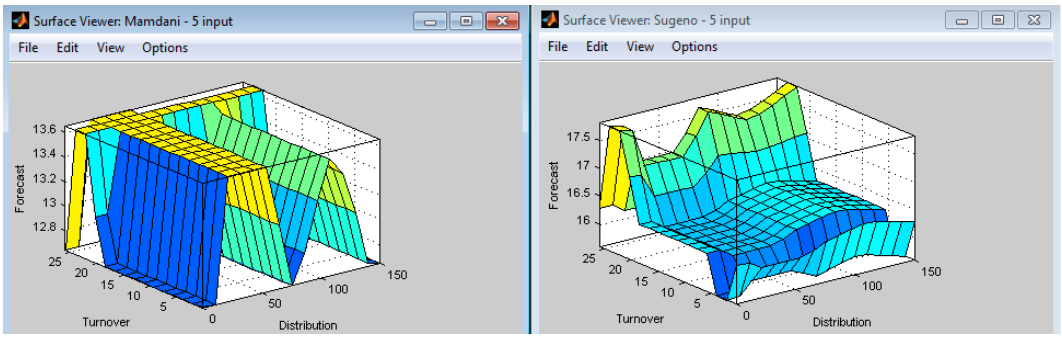
For 50% of the graphic form of 3D surfaces was about the same size but different forecasting (eg Fig. 6).




a. Mamdani b. Sugeno

**Fig. 6** Comparison Mamdani vs Sugeno surfaces for Forecasting based to Fidelity and Turnover

For the remaining 50% of the graphics 3D surface shape was completely different and distinct from the size of the forecasting (e.g. Figure 7).




a. Mamdani b. Sugeno

**Fig. 7** Comparison Mamdani vs Sugeno surfaces for Forecasting based Distribution and Turnover

## 5. Conclusions

When Mamdani and Sugeno FIS performance patterns are compared with each other, in some cases are very close and others are contradictory. If the FIS model results are compared to the conventional methods, the results of all FIS models are better than those predicted by conventional methods. In order to validate performance models FIS, comparisons were made to capture as many interdependencies between input. Fuzzy rule-based systems, have a great capacity for processing the input variables and performance of these systems, they can be improved by optimizing the selection of characteristics and selection rules.

As Mamdani FIS FIS conclusion is appropriate to use when we have only one output variable (multi-input-single-output - MISO) and Sugeno FIS if necessary division of multi-input multi-output (MIMO) in as more MISO systems the number of output variables (complex and time-consuming method).

Future studies aim to optimize for both methods so that the final FIS best method FIS to be made for a unified analysis of the result in 3D space and time.

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