

Application of fuzzy logic in assessing the risk of arterial occlusion in hypertensive patients

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Abstract: The solutions to most of the problems a person faces in life are imprecise or non-deterministic. The inaccuracy results either from the lack of data collected from a particular problem, and this data is vague, inaccurate, or incomplete, which leads to a lack of information. Or from differences of opinion on a particular issue. The data on occlusive arterial disease was analyzed using the fuzzy system, and one of the most important conclusions reached in this research is that the basis of fuzzy logic is based on medical conclusions based on extensive statistical studies on facts about normal and pathological measurements in different environmental conditions. Its accuracy depends on the accuracy of the basic conclusions. Fuzzy logic can be considered an alternative to statistical studies if it is fed with direct clinical information.

Research objective: The aim of the research is an expert computer system to predict the degree of people suffering from obstructive arterial diseases using the FCM algorithm and the laws of the fuzzy system in order to obtain the best fuzzy cluster and compare the results with the designed fuzzy system. The research was applied to medical data, including data on high blood pressure, total cholesterol, and cholesterol that is good for the body, and the results were extracted in the programming language - MATLAB. The results obtained from the fuzzy system are compared with the real data.

Fuzzy logic: It is a special logic based mainly on fuzzy set theory. Fuzzy sets are sets with no categorical limits and are a generalization of the classical sets developed by Georg Cantor. Traditional set theory relies mainly on the traditional logic developed by Aristotle before

Christ. This logic is extreme and takes into account only the thing and its opposite. Such logic no longer meets the requirements of the new mathematical and logical understanding in contemporary scientific thought. The scientist Lutfi Zadeh is considered the inventor of fuzzy logic in 1965 [Sivanandam 2007], which he later developed to use it in a better way to process data, ambiguities, and loss of precision in problems, by applying a more human-like way of thinking to data programming. Although accuracy is required when dealing with simple systems, it is not necessary and sometimes not required when dealing with complex issues. Zadeh presented a linguistic method for dealing with ambiguous linguistic information in which he described the mathematical basis based on fuzzy set theory. This theory was assumed by making the belonging function or true and false values operate over the range of real numbers within the interval [0-1] [Mathworks1999]. Among the important contributors to the development of fuzzy logic are the researcher Tanaka in his research "Stability Analysis of Control Systems," the researcher Mamdani in his research on the control of cement furnaces, Kosco and Biederz in fuzzy neural networks, and Bazdak in pattern classification. [Sivanandam 2007].

Applications of fuzzy logic: After the great demand for fuzzy logic in recent years, the total number of goods that were manufactured using fuzzy logic reached more than two thousand industrial products during the year 1996, and this production was distributed between heaters and washing machines. When moving between these industrial products, it is noted that each of the aforementioned applications He has taken advantage of the advantages of fuzzy logic such as high performance, simplicity, low cost and high throughput and has found that fuzzy logic is a very suitable technology for applications in control units. Large numbers of factories have automatic production lines that rely in their production on fuzzy logic technology to improve the quality of the product and shorten the development time. Fuzzy logic helps in confronting and treating very complex real-time problems by using simple directions to solve these problems, and it also helps to improve the production time. Marketing and cost reduction in electronic industries, and in manufacturing it proves that it is an indispensable technology in increasing the efficiency of production lines and diagnosing their faults. It has also been used in the field of controlling the cement manufacturing system, and other applications that benefited from fuzzy logic, such as in the field of information retrieval systems, and in The field of controlling the driving of automated wheels, as well as controlling automated operations on

trains and in laboratories for measuring water levels, and in controlling the arms of a robot and the commands directed to it (Brule J. 1985).

Fuzzy set theory: Fuzzy set theory is a generalization of normal set theory, which was proposed by Lotfi Zadeh in 1965. In normal set theory, any element either belongs to the set or does not, and these sets are usually called crisp sets. On the other hand, in fuzzy sets, the element has partial membership with respect to that set, and thus the fuzzy set can be defined as a partial set of the global set, The elements in it can be partially related, and their degree of belonging is called the membership degree, which are real numbers that fall within the closed interval. [0,1] If the membership degree is zero, then the item does not belong to the group. However, if the membership degree is one, this means that the item belongs to the group with a membership degree of 100%, meaning its membership is complete. This differs from the Characteristic function for the fragile set, where the value of each element in the comprehensive set is assigned to be either zero or one [Hindush 2003].

The normal group and the fuzzy group: The main difference between brittle and fuzzy sets is that the membership function of a brittle set is single, while in a fuzzy set it can take a number of membership functions to represent it. As for the normal (fragile) group: it has precise boundaries, and membership or affiliation to a group is determined with complete certainty, because any element in society is either a member of the group or not. We encounter many issues in our daily lives, as well as in groups, issues that we cannot define definitively, such as the “old buildings” group or the “high blood pressure” group, etc. So we find that there are many groups that include ambiguous linguistic concepts such as “old”, “high”, “long”, “hot”, etc. They cannot be completely represented by classical sets, and fuzzy sets are the natural way to characterize such concepts (Klir et al (1997)) and ordinary sets can be represented mathematically in the following formula: [Timothy J. Ross 2002].

$$\mu_A(x) = \begin{cases} 1 & \Leftrightarrow x \in A \\ 0 & \Leftrightarrow x \notin A \end{cases}$$

Where it gives the degree of membership of element x in the normal group.

Fuzzy set: It is a set characterized by the fact that its boundaries are flexible and not definitive, and its boundaries cannot be defined in a clear and precise way [Mathworks 1999], that is, in it one avoids the limit logic (it belongs or it does not belong), because ambiguity is always present in any realistic process. If X represents the Universal Set, then the fuzzy set A of Zadeh 1965]:

$$A = \{x, \mu_A(x)\} \quad \forall x \in X$$

Where it is the membership function of element x in the fuzzy set A. The membership function of the fuzzy set can be represented mathematically by the following formula, and Figure (2-1) shows the regular set and the fuzzy set:

$$\mu_A(x) \in [0,1]$$

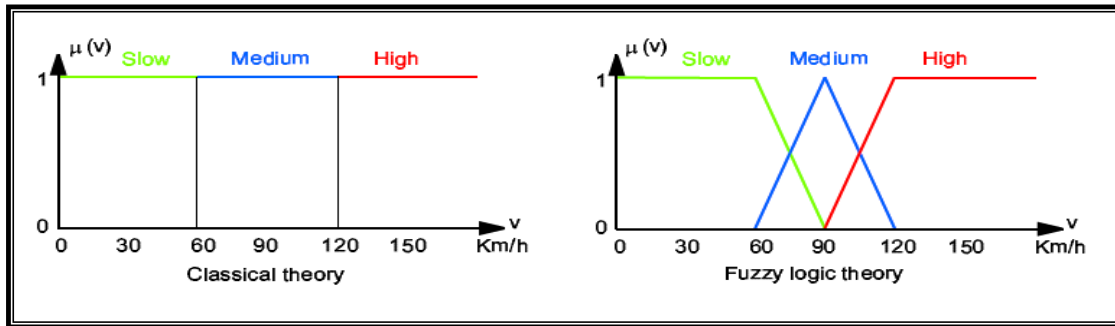


Figure (1) shows a comparison between the regular group and the foggy group

Logical operations in fuzzy logic: When we mention fuzzy sets, we come to mind the operations performed on regular sets and the possibility of applying these operations to fuzzy sets. Given that the fuzzy set is a partial set of the comprehensive set, the operations that are performed on regular sets can be performed on fuzzy sets, but in another sense that differs from that concept in regular sets. In general, there are two types of operations: standard logical operations (ordinary operations) and fuzzy logical operations [Hamouda 2002]. In the first type there are operations (AND, OR, NOT) that are the same as the well-known traditional operations, but in the second type the fuzzy logic functions will differ. By taking the values between 0 and 1, they are as follows: [Klir 2007], Assuming that A and B are two fuzzy sets defined on the comprehensive set.X

The process of the fuzzy complement: The complement of the fuzzy set A is symbolized by \bar{A} : It has a membership function defined by the following formula, and Figure (2) shows the form of the fuzzy set and its complement:

$$\mu_{\bar{A}}(x) = 1 - \mu_A(x) \quad , \quad \forall x \in X \quad \text{[Zhenyuan Wang 2010]}$$

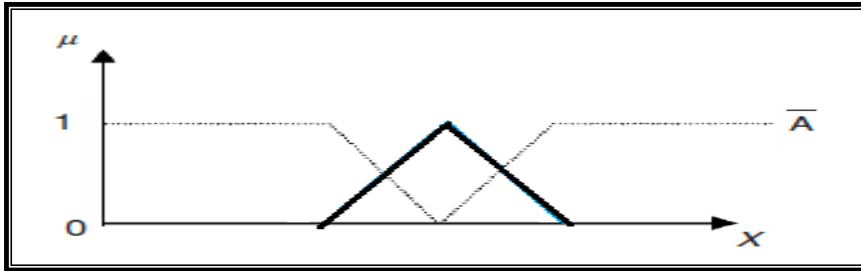


Figure (2) represents the fuzzy complement process.

- **The fuzzy union process:** The fuzzy union of the two sets B and A is symbolized and defined by the membership function in the following formula, and Figure (3) shows the fuzzy union process: [Zhenyuan Wang 2010].

$$\mu_{A \cup B}(x) = \mu_A(x) \vee \mu_B(x) = \text{MAX} \{ \mu_A(x), \mu_B(x) \} \quad \text{for all } x \in X$$

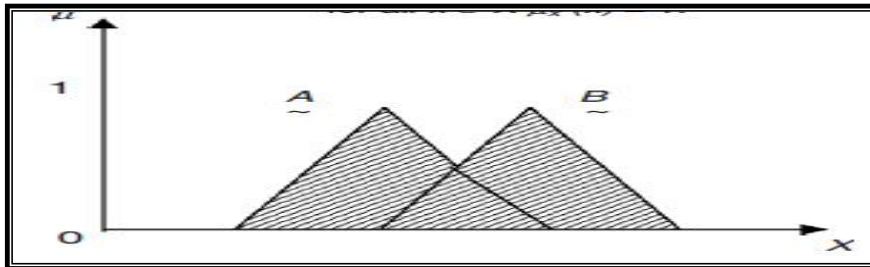


Figure (3) shows the fuzzy union process.

- **The fuzzy intersection process:** The fuzzy intersection of the two sets B and A is denoted by the symbol, and is defined through the following membership function. Figure (4) shows the fuzzy intersection process: [Zhenyuan Wang 2010].

$$\mu_{A \cap B}(x) = \mu_A(x) \wedge \mu_B(x) = \text{min} \{ \mu_A(x), \mu_B(x) \} \quad \text{for all } x \in X$$

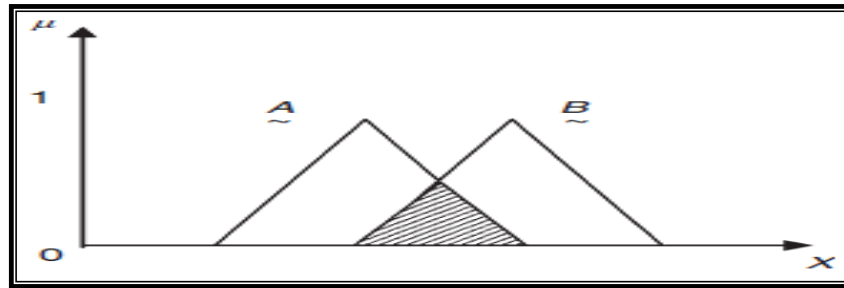


Figure (4) shows the fuzzy intersection process.

Membership functions: One of the primary motivations for creating fuzzy sets is to deal with concepts of a special nature that cannot be determined definitively. Given that membership in a fuzzy set can have uncertainty, membership in a fuzzy set is a matter of degree of membership in that group. Every fuzzy set is defined for a superset, It is symbolized by $\mu(x)$ And every element x is in the universal set X , It has a value in the closed interval $[0,1]$ and is usually represented by the following formula. Figure (5) shows the general representation of the membership function: [Klir 1997].

$$\mu(x): X \rightarrow [0,1]$$

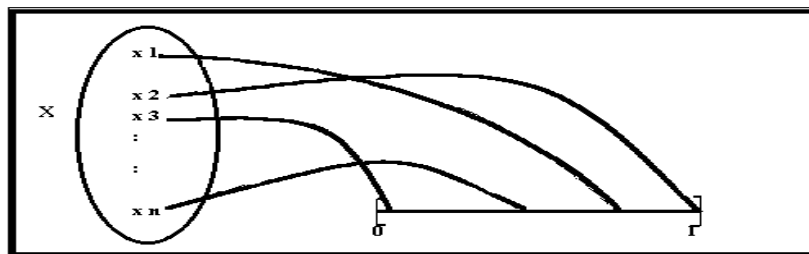


Figure (5) shows the general representation of the membership function.

Representing organic functions: Organic functions can be represented in more than one way, and we will talk about the most common of these methods, which are:

1- Graphical representation: This representation is one of the most common methods, as the membership function is represented by a specific curve that can be chosen depending on the nature of the issue. Figure (6) shows a set of common curves that are used for this purpose [Klir 1997].

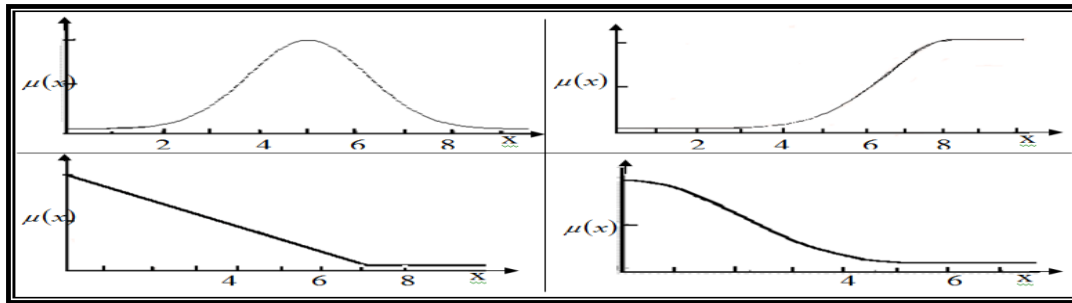


Figure (6) shows some common curves used for graphical representation.

2- Tabular Representation: The graphical representation is applicable to membership functions whose comprehensive sets are either one-dimensional Euclidean space or two-dimensional Euclidean space. Therefore, there is a need to introduce other methods to represent finite comprehensive sets, including the use of tables. Usually, the table representing the fuzzy set includes all the elements in the comprehensive set and their corresponding membership degrees. This method is used when characterizing the fuzzy set of group members associated with degrees of group membership [Klir 2003].

3- Geometric representation: Membership functions in fuzzy sets can be represented in geometric terms. Let Each element in X can be viewed as a coordinate in an n -dimensional Euclidean space, $X = \{x_1, \dots, x_n\}$. If we limit the values of each coordinate of the real numbers to the interval $[0,1]$, we will obtain a subset of the Euclidean space, which is called the unit cube with dimension n . Each point in the unit cube is uniquely characterized by coordinate values that are all in the interval $[0,1]$. If these values are interpreted as membership degrees for the elements in the fuzzy set, then the point represents the fuzzy set itself. This means that all fuzzy sets can be defined as a universal set of n elements that can be represented by points in an n -dimensional unit cube [Klir 2003].

4- Analytical representation: When the comprehensive set is infinite, in this case it is not possible to list all the elements of the set of real numbers together with their membership degrees [Klir 2003]. There are types of functions of belonging, which are:

- **Triangular Membership Function:** This function is characterized by three parameters a , b and c , where a and c represent the lists of the trigonometric function and the value of b represents the vertex of the triangle: [Klir 2003].

$$\mu(x) = \begin{cases} 0 & ; & x \leq a \\ \frac{x-a}{b-a} & ; & a \leq x \leq b \\ \frac{c-x}{c-b} & ; & b \leq x \leq c \\ 0 & ; & c \leq x \end{cases}$$

- It can be represented in the following formula and Figure (7) shows the trigonometric belonging function:

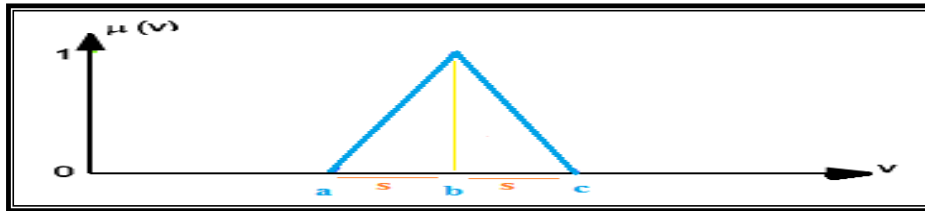


Figure (7) shows the triangular belonging function.

- **Trapezoidal Membership Function:** This function is characterized by four parameters a, b, c, d, where a and d represent the lower vertices of the shape while b and c represent the upper vertices. It can be represented in the following formula and Figure (8) shows the trapezoid function:

$$\mu_A(x) = \left\{ \begin{array}{ll} \frac{(x-a)}{b-a} & ; \quad a \leq x \leq b \\ 1 & ; \quad b \leq x \leq c \\ \frac{(d-x)}{d-c} & ; \quad c \leq x \leq d \\ 0 & ; \text{otherwise} \end{array} \right\}$$

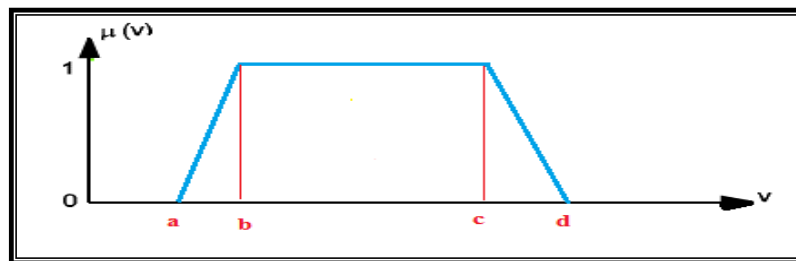


Figure (8) shows the trapezoidal function.

- **Membership Function Bell-shaped, called the Gaussian Function:**

This function is characterized by two parameters, b and c , where $b = 2\sigma^2$ the parameters c and σ represent, respectively, the upper vertex of the shape and the distance of the edges from the center of the shape.

$$\mu_A(x) = e^{-\frac{(x-c)^2}{b}}$$

The function can be represented in the following formula, and Figure (9) shows the bell function:

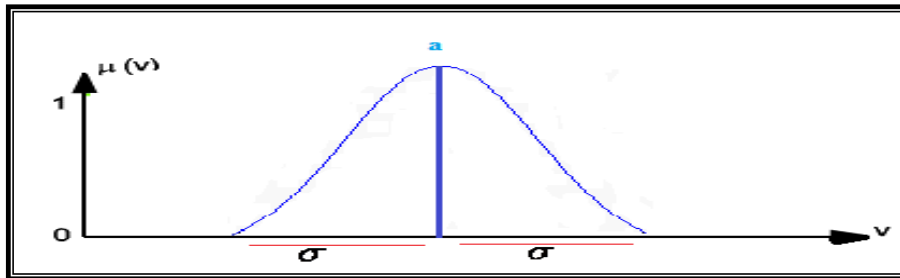


Figure (9) shows the bell-shaped function.

Features or phenomena of membership functions: The features of membership functions are known by three properties:

1. Core.
2. Support.
3. Boundary.

These are the standard areas of knowledge in the organic functions, and they know two important terms:

1- Intersection point: The intersection point of the membership function is the elements whose membership value is equal to 0.5

$$\mu_A(x) = 0.5$$

2- Height: The height of the fuzzy set A is the maximum value of the membership function

$$\max = \mu_A(x) \quad [\text{Sivanandam 2007}]$$

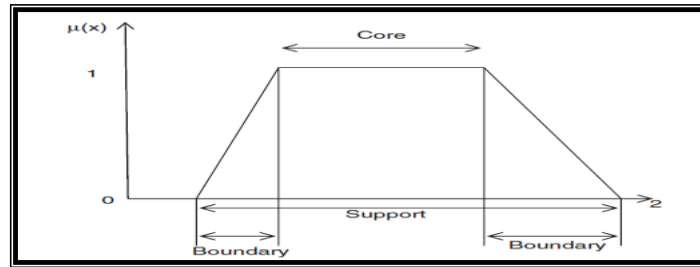


Figure (10) shows the features of membership functions.

Fuzzy control systems: The theory of fuzzy systems is an alternative choice to the traditional views on the degree of membership of an element in a group and to the logic that originally goes back to the Greek philosophers. This field has been used in many fields, and has brought about great development in them, such as the field of control, where fuzzy controllers are known. Controller is a simple conceptual concept consisting of an input phase, a processing phase, and an output phase:

Input stage: It converts the input into the appropriate membership function and then into real values.

The processing stage: This is the stage in which each appropriate law or rule is simulated and then the results are linked to the appropriate laws or rules.

The output stage: It converts interconnected results into output values that determine control in a specific topic.

Requirements for creating a fuzzy system: There are a set of requirements that must be determined when creating a fuzzy system, which are:

- Number, type and range of both input and output.
- Membership functions for both input and output.
- Laws (rules).

[Bydon S. 2001]

Stages of building the fuzzy model : A fuzzy model is an expert system that explains the relationship between inputs and outputs through a set of rules. The fuzzy model is usually built in three basic steps:

- **Fuzzification:** The fuzzification step is the first step in the process of building a fuzzy model, which converts fragile inputs into fuzzy inputs using membership functions. Fuzzing means calculating the membership value of each entry in the fuzzy set [Malaviya Ashutosh 2000]. Membership functions take different forms, including trigonometric, trapezoidal, etc., whose membership values are limited to zero and one. [Hindosh 2003]
- **Rule Evaluation:** In this step, we transform fuzzy inputs into fuzzy outputs using rules. This is done by three points:
 1. Creating a rule-base in which linguistic rules are used.
 2. Determine the validity values of the logical premise.
 3. Determine the fuzzy output of the logical result.
- **Defuzzification:** which works to transform fuzzy outputs into fragile outputs that take real numerical values, and the blurring is removed using special methods, including:
- **Maximum Membership Principle:** This method selects the element that has the highest membership degree value.

$$\mu_c(z^*) \geq \mu_c(z) \quad \forall z \in Z$$

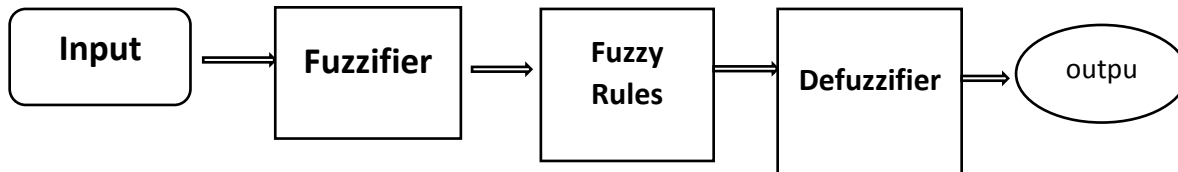
- **Centroid method:** Using a point in the fuzzy solution space that represents the center of the fuzzy group in the interval [a, b] as in the following formula:

$$z^* = \frac{\int \mu_c(z)zdz}{\int \mu_c(z)dz}$$

- **Weight average method:** The weight average method is in the form of a membership function for each weight in the output with the highest private membership values. It is considered a special case of the centering method as it is used only for identical output membership functions, as in the following formula:

$$Z^* = \frac{\sum \mu_c(\bar{z})\bar{z}}{\sum \mu_c(\bar{z})}$$

The following diagram shows the stages of building the fuzzy system:



Reasons for using fuzzy models in systems: There are a number of reasons for using fuzzy models in systems, which can be summarized as follows:

1- Incomplete or ambiguous knowledge about the system: There is a group of systems for which we can obtain mathematical models, such as mechanical-electrical systems, through the physical laws surrounding the system, and thus rules or laws can be deduced to create a fuzzy model that constitutes a specific system, and with regard to large numbers of problems and applications. In the process, the process of collecting complete knowledge about these applications is difficult and leads to consumption of cost and time. It is also possible that the work is not completed in most systems. Examples of such systems can be found in food or chemical factories, in environmental science, in life technologies, in financial science, and even in sociology...etc. An important part of the information about such systems can be obtained from the experience of scientists, experts in these fields, or designers. Here, rule-based fuzzy systems are used that are used as models based on the knowledge of experts in a particular field.

2- Providing accurate processing of ambiguous information: Using precise numerical calculations with traditional mathematical models is only effective when the variables and input data are accurately known. The modeling framework requires not only processing the given data but also dealing with uncertainty or ambiguity. A group of methods have emerged to deal

with cases of ambiguity, including fuzzy logic or fuzzy set theory, which is considered one of the most successful methods for dealing with this situation [Al-Dewji 2003] .

3- Providing clear system modeling and diagnosis: The process of diagnosing fuzzy models is an effective tool in dealing with fuzzy systems based on the data used. The process of diagnosing fuzzy models using inputs and outputs includes diagnosing the general structure of the system, by determining the type and number of rules used in the system and the number of membership functions. Also, prior knowledge about the system plays an important role in the system design phase. Diagnosing motor systems through inputs and outputs is a very important topic in practical research with a wide range of applications, as many systems in the real world are non-linear systems and cannot be represented by linear models used in traditional systems. Nowadays, there is a great emphasis on developing methods for diagnosing nonlinear systems using available data, and artificial neural networks and fuzzy models belong to these common methods. By seeing the inputs and outputs, fuzzy systems can be expressed as flexible mathematical functions, and fuzzy systems provide a clear representation of the system under study, because fuzzy systems provide the property of dealing with linguistic variables with rules, and the logical structure of the rules facilitates understanding and analyzing the model in a similar way. To some extent for human reasoning in real life [Al-Duji 2003] Abonyi J. 2003.

- **Fuzzy inference system:** We can find fuzzy inference systems under different names, including fuzzy rule-based systems, fuzzy expert system, fuzzy mode, and fuzzy associative memory. The fuzzy inference system formulates appropriate rules, and based on the rules makes a decision, and this is basically based on the principles of fuzzy set theory. The fuzzy reasoning system uses the IF THEN statement, as well as the connectors in the rule statement, namely or and and, to create rules necessary for decision making. A fuzzy inference system can take fuzzy inputs or regular inputs, but the resulting output is most often fuzzy sets. When

using the heuristics system as a controller, it is necessary to have a fragile output. Therefore, the defuzzification method is used to obtain the best extracted brittle value, which best represents the fuzzy set [Sivanandam 2007].

Fuzzy inference methods: There are two models of fuzzy inference models:

- Mamdani reasoning model.
- Takagi-Sugeno-kang reasoning model.

The most important type of these two models is the Mamdani fuzzy inference model, which is the most common method. This model was presented by researchers Mamdani and Assilian 1975. The other model is the fuzzy Sugeno model or the Takashi-Sugino fuzzy method, which was presented by researcher Sugeno 1985. The main difference between the two models lies in the fuzzy rule sequences. Mamdani systems use fuzzy sets as results, while Sugeno systems employ linear functions of input variables as products of a rule [Sivanandam 2007].

1. Mamdani fuzzy model: This model is the most common of the fuzzy models, and was among the first control systems based on the use of fuzzy set theory as an attempt to control a steam machine and boiling tank by installing a set of linguistic control rules derived from experimental human operators. Mamdani's effort was based on Lotfi Zadeh's 1973 research on fuzzy algorithms for complex systems. Mamdani's inference model expects the output membership functions to be a fuzzy set. In order to calculate the output, the given input follows several steps, which are:

- Define the fuzzy set of rules.
- Fuzzing the inputs using input membership functions.
- Connect fuzzy inputs according to fuzzy rules to establish the strength of the rule.
- Find the result of the rule by linking the strength of the rule and the output membership function.

- Link the results to obtain the output. [Sivanandam 2007].

In this model, the defuzzification process is applied to the fuzzy set resulting from the sum of the fuzzy sets for each rule in the Consequent part, as the output is represented in the form of fuzzy sets, relying on the (IF-THEN) rule and the following formula. It explains how the output is represented. Figure (11) shows two inputs and two rules for a fuzzy Mamdani system with a fuzzy output [Jang 2009]:

$$R_i : IF x \text{ is } A_i \text{ THEN } Y \text{ is } B_i \quad i = 1, 2, 3, \dots, K$$

A_i : represents precedence parameters (Antecedent).

B_i : represents the set of dependent products (Consequent).

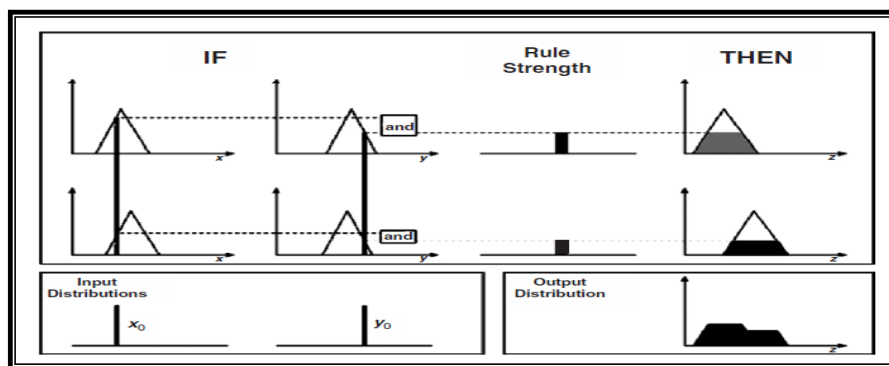


Figure (11) shows two inputs and two rules of a fuzzy Mamdani system with a fuzzy output.

2- Takachi Sugeno's Fuzzy Model: Takachi Sugino presented an innovative type of modeling process, which later became one of the main topics in theoretical studies and practical applications [1995] [Charlie Dou. This model generates fuzzy rules from the input and output data set, and the output () is calculated By taking the average weights of the rules, the output is represented in the form of constant values, as in the following formula [Babuska 2002]:

$$R_i : IF x \text{ is } A_i \text{ THEN } Y_i = a_i^T x + b_i \quad i = 1, 2, 3, \dots, K$$

a_i : a vector of function parameters.

b_i : Adjustment scale.

The weighted average of the rules is also calculated through the following equation:

$$Y = \frac{\sum_{i=1}^K \beta_i(x) y_i}{\sum_{i=1}^K \beta_i(x)} = \frac{\sum_{i=1}^K \beta_i(x)(a_i^T x + b_i)}{\sum_{i=1}^K \beta_i(x)}$$

Where: $\beta_i(x)$ membership function.

In a special case, when the output is of zero order (Zero-Order Polynomials), the function is as follows:

$$R_i : IF x \text{ is } A_i \text{ THEN } Y = b_i \quad i = 1, 2, 3, \dots, K$$

$$Y = \frac{\sum_{i=1}^K \beta_i(x) b_i}{\sum_{i=1}^K \beta_i(x)}$$

$$\mu_{B_i}(x) = \begin{cases} 1 & ; y = b_i \\ 0 & ; otherwise \end{cases}$$

Applied part: Genetic diseases: The number of known genetic diseases exceeds (4000) diseases, and this number is likely to increase due to successive discoveries of the causes of diseases (Al-Jishi 2008). Blood pressure is a genetic disease and is defined as the force exerted by blood on the walls of blood vessels as it flows through them. Blood pressure results from the force of the heart pumping blood. High blood pressure occurs when the ventricles of the heart contract, while low blood pressure occurs when the heart rests [Colledge, N.R. 2010]. High blood pressure (Hypertension) is a condition that indicates a chronic increase in blood pressure. With every heartbeat, the heart pumps blood through the arteries to the rest of the body. If blood pressure is high, the heart needs to exert greater effort to pump blood, and this may lead to damage to the organ in question or to a specific disease such as a heart attack, stroke, heart

failure, blood cyst, kidney failure, or bleeding within the retina. Blood pressure is classified as essential or secondary.

1. Essential blood pressure is the term given to high blood pressure without a direct cause of a specific disease, and it includes 95% of cases of chronic hypertension.
2. Secondary blood pressure is the term given to high blood pressure as a result of a disease causing it, such as kidney disease, tumors, or birth control pills.

The main cause of high blood pressure is usually unknown, but there are several factors that contribute significantly to increasing the risk of high blood pressure, and these factors include: smoking, obesity/overweight, diabetes, lack of physical activity, and an increase in the level of salts in the blood (sodium). In particular), calcium, potassium and magnesium deficiency, vitamin D deficiency, increased alcohol consumption, nervous tension, aging, certain medications such as birth control pills, pain relievers, genetic causes, chronic kidney disease, adrenal gland problems or Thyroid disease, certain tumors [Peter 2009].

The World Health Organization has classified high blood pressure levels into five categories, and this classification has been relied upon in the current field of research. Table (1) shows the classification of blood pressure according to the World Health Organization: [American Heart Association 2009]

Table (1): Classification of blood pressure according to the World Health Organization.

SBP	Optimal	Normal	Mild	Moderate	Severe
Rang	80-120	120-130	130-140	140-160	160-180

- **Medical data:** The data includes readings for age, gender, smoking, high blood pressure, total fat, beneficial body fat, and the risk ratio for two hundred and six patients, and represents the probability of a person's risk of developing clogged arteries in the next ten years. The risk rate was determined by Dr. Amer Abdul Haq Al Nuaimi and Dr. Omar Mohsen Muhammad Ghazal based on the book (Davidson 2010).

-Describe the designed system: The prepared system consists of 12 fuzzy partial systems. Each partial system calculates a person's risk of developing clogged arteries within ten years, taking into account that each fuzzy partial system performs treatment according to the sex, age, and smoking status of each patient, and these variables have a major role in the treatment. Determine the risk rate. The fuzzy partial system examines the inputs and outputs, and then determines the output. The fuzzy partial systems were combined with the GUI interfaces to create an integrated system. Therefore, we used the GUI to classify the variables (gender, age, and smoking) and we used the fuzzy system for the variables (high blood pressure, total fat, and beneficial body fat). This was done using the Matlab language, as this language has several features that made it possible to design a fuzzy computer system. One of these features is the possibility of Fuzzy customization as well as the ease of building functions and interfaces used in the system for the purpose of completing the necessary boot operations.

Data Analysis (System Application): The system is implemented by entering data that represents medical examinations into the system through the interface designed for this purpose. The fuzzy system is accessed through the function (readfis (file_name.fis)), and this function reads the fuzzy system, which is in a file called men (nonsmoker age 60 over.fis) and gives it to a specific variable, let it be Sys, and then the function (evalfis) which contains two variables: the first represents the input to the system, and the second represents the system's variable, as follows:

```
sys =readfis("men nonsmoker age 60 over.fis ");
```

```
comp_str=evalfis ([SBP TC:HDL] , sys );
```

The first sentence is merely converting the system into a variable such as sys, which represents the way the system is interacted with, meaning data is entered into and exited from the system. As for the second sentence, it is the process of entering data into the system and taking output from it.

The data was applied to the designed system and the result was compared with the actual output values and the results were as follows:

The first system: represents (women, non-smokers, under 50 years of age) and Table (2) shows the results:

Table (2) represents a comparison between the real results and the results of the first partial system.

	SBP	TC:HDL	Fuzzy	Real	Error of Fuzzy
	130	4.310924	5.00204	5	0.000004
	120	4.553571	5.00204	4	1.004084
	145	7.125	15	13	4
	165	4.241667	5.00204	8	8.987764
	160	6.448718	15	14	1
	145	3.3	5.00204	5	0.000004
	145	4.9	5.00198	6	0.996044
	125	6.108696	5.00161	8	8.990343
	130	3.413333	5.00204	4	1.004084
	145	6.421053	13.1213	12	1.257314
	135	3.545455	5.00204	4	1.004084
	140	3.066667	5.00204	4	1.004084
	145	4.98	5.0014	7	3.994402
	140	3.0132	5.002	5	0.000004
	160	7.9429	15	16	1
	135	6.5053	5.002	8	8.988004

	135	3.6449	5.002	4	1.004004
	145	3.2059	5.002	6	0.996004
					MSE=2.51279

The second system: represents (women, non-smokers, aged between 50-59), and Table (3) shows the results:

Table (3) represents a comparison between the real results and the results of the second partial system

	SBP	TC:HDL	Fuzzy	Real	Error of Fuzzy
.	150	5.7053	15	15	0
.	177	6.1099	19.3	20.3	1
.	160	4.1569	15	14	1
.	145	3.8438	9.7	9.8	0.01
.	160	4.2	15	14	1
.	140	4.8281	15	12	9
.	150	4.6089	15	14	1
.	120	5.5283	15	11	16
.	150	5.2049	15	15	0
0.	135	3.8377	5	6	1
1.	175	6.7237	25	22.5	6.25

2.	160	4.5383	15	14	1
3.	150	3.8615	9.7	10	0.09
4.	140	3.8201	9.7	9	0.49
5.	150	5.6569	15	16	1
6.	140	5.1731	15	13	4
7.	160	4.4259	15	14	1
8.	145	3.8374	9.7	9.9	0.04
9.	175	7.375	25	25	0
0.	170	5.9796	16.3	19	7.29
1.	165	3.6019	15	12	9
2.	130	3.2165	5	6	1
3.	150	3.8879	9.7	10	0.09
4.	125	4.1261	5	8	9
5.	160	9.3429	25	28	9
6.	150	5.7558	15	16	1
7.	175	4.4338	15	17	4
8.	170	3.15	15	13	4
					MSE= 3.152142857

The third system: represents (women, non-smokers, aged more than 60 years and above), and table (4) shows the results:

Table (4) represents a comparison between the real results and the results of the third partial system.

	SBP	TC:HDL	Fuzzy	Real	Error of Fuzzy
1	150	3.5214	5.002	10	24.980004
2	130	3.2339	5.002	7	3.992004
3	150	4.0534	13.5992	13	0.35904064
4	120	3.4267	5.002	5	0.000004
5	170	5.8739	24.9981	23	3.99240361
6	150	4.2783	15	13	4
7	177	4.6292	15	19.9	24.01
8	160	3.7632	15	15	0
9	178	4.1328	15	19.5	20.25
10	160	3.9313	15	15	0
11	170	5.2541	24.998	22	8.988004
12	150	4.8571	15	16	1
13	170	4.9322	20.0849	20.5	0.17230801
14	155	4.126	15	15	0
15	175	5.2377	24.998	23	3.992004
16	160	5.5041	24.998	21	15.984004

17	165	8.5135	24.998	26	1.004004
18	150	6.13294	19.9296	19.9	0.00087616
19	165	4.3294	15	18	9
20	150	4.8596	15	16	1
					MSE =5.820730403

The fourth system: represents (women, smokers, aged less than 50 years or younger), and table (5) shows the results:

Table (5) represents a comparison between the actual results and the fourth partial system results.

	SBP	TC:HDL	Fuzzy	Real	Error of Fuzzy
	125	2.51282051	5.00204	4	1.004084162
	115	3.69911504	5.00207	5	0.0000042
	130	2.31016043	5.00204	4	1.004084162
	130	6.07407407	15	15	0
	115	3.33333333	5.00204	4	1.004084162
	120	2.84023669	5.00204	4	1.004084162
					MSE =0.669390155

The fifth system: represents (women, smokers, aged between 50-59), and table (6) shows the results:

Table (6) represents a comparison between the real results and the fifth partial system results.

	SBP	TC:HDL	Fuzzy	Real	Error of Fuzzy
1	160	9.2857143	24.998	28	9.012004
2	165	7.5714286	24.998	26	1.004004
3	150	5.8	24.998	23	3.992004
4	150	3.8461538	15	17	4
5	160	6.375	24.9977	25	5.29E-06
6	140	4.25	15	17	4
					MSE =3.668002882

The sixth system: represents (women, smokers, over 60 years old). Table (7) shows the results:

Table (7) represents a comparison between the real results and the results of the sixth partial system.

	SBP	TC:HDL	Fuzzy	Real	Error of Fuzzy
1	120	5.1578947	15	19	16
2	125	3.3	15	15	0
3	175	3.357143	24.998	22	8.988004
4	170	3.5597015	15	19.9	24.01

5	175	6.8117647	24.998	21	15.984004
6	162	5.5425532	24.998	23	3.992004
7	130	5.1	22.45	24	2.4025
					MSE =10.1966446

Through the results reached by this research as follows:

1. The basis of fuzzy logic is reliance on medical conclusions based on extensive statistical studies on facts about normal and pathological measurements in different environmental conditions. Its accuracy depends on the accuracy of the basic conclusions. Fuzzy logic can be considered an alternative to statistical studies if it is fed with direct clinical information.
2. Expanding the use of fuzzy logic in various fields of life (medicine, quality control, earth sciences).
3. Introducing the philosophy of fuzzy logic into the medical and life fields because these fields are a very suitable environment.
4. Developing the computer system prepared in this thesis to include other variables that are important from a medical standpoint (such as diabetes input, degree of obesity, low blood pressure), as well as training on larger data.
5. Developing the prepared system by providing clinical information for each person and conducting tests to determine the extent of the artery's vulnerability to blockage and comparing it with the prepared system.

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