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Classify the Nutritional Status of Iraqi children under Five Years Using Fuzzy Classification

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Abstract

In this paper, we applied the theory of Fuzzy Sets to classify the nutritional status of children under five years of age using fuzzy logic and two fuzzy classification methods (Mamdani and Sugeno). We relied on linguistic variables (weight and height) to categorize children into more accurately defined categories of nutritional status. The goal is to minimize the chances of misdiagnosis and provide precise treatment for each category, thus contributing to the creation of a more resilient society with high levels of health. In this study, we employed a sample of 16,487 Iraqi children under the age of five years, divided into 12 age categories.

The results, after calculating the classification accuracy criterion, showed that among the two methods compared to the classical classification, the Sugeno method proved to be the best, with an accuracy level of around 60% for various age categories for both males and females.

Keywords: Fuzzy Classification, Mamdani, Sugeno, Nutritional Status.

تصنيف الحالة التغذوية للأطفال العراق دون سن الخمس سنوات باستعمال التصنيف الضبابي

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الخلاصة

في هذا البحث، طبقنا نظرية المجموعات الضبابية لتصنيف الحالة التغذوية لأطفال العراق دون سن الخامسة باستعمال المنطق الضبابي وتم استعمال طريقتين للتصنيف الضبابي (Mamdani, Sugeno) اعتمدنا على المتغيرات اللغوية (الوزن والطول) لتصنيف أطفال العراق حسب الحالة التغذوية إلى فئات محددة بشكل أكثر دقة. الهدف من التصنيف هو تقليل فرص التشخيص الخاطئ وتوفير علاج دقيق لكل فئة للمساهمة في تحسين الوضع الصحي بالنسبة للأطفال، في هذه الدراسة استعملنا عينة مكونه من 16487 طفلا عراقيا دون سن الخامسة، مقسمة إلى 12 فئة عمرية .أظهرت النتائج بعد حساب معيار دقة التصنيف بعد مقارنة الطريقتين مع التصنيف الكلاسيكي المستعمل في المراكز الصحية في العراف وأثبتت طريقة سوجينو أنها الأفضل بمستوى دقة يقارب 60٪ لمختلف الفئات العمرية لكل من الذكور والإناث.

الكلمات المفتاحية: التصنيف الضبابي، طريقة مامديني، طريقة سوجينو، الحالة التغذوية.

1. Introduction

The child nutrition has garnered the attention of numerous researchers worldwide and in various societies, as it reflects the growth of these communities, particularly concerning the pivotal category of children who are the foundation of society. One of the indicators of child health is nutritional status, where the World Health Organization estimates that around 3 billion people suffer from malnutrition of some form. In 2014, more than 1.9 billion adults, representing about 39%, were overweight, while over 600 million individuals, around 13%, were affected by obesity. Since 1980, obesity has more than doubled worldwide. [1]
In 2014, there were 41 million children under the age of 5 affected by obesity. Additionally, the issue of weight gain and obesity, once considered a problem primarily in high-income countries, is now on the rise in low and middle-income countries as well. [2] Meanwhile, focusing on the health aspect of children and ensuring proper nutrition leads to a strong immune system that aids in combating infectious diseases. [1] In the developing world, malnutrition affects nearly 800 million individuals, with over 340 million of them being children under the age of five. More than six million of these children die each year due to malnutrition. The majority of the world's population lives in countries where overweight and obesity claim more lives than underweight. [2]

Several factors contribute to the widespread prevalence of malnutrition among children, including low birth weight, inadequate nutrition, the prevalence of infectious diseases, lack of breastfeeding, and improper childcare practices. Malnutrition is known to be a contributing factor to diseases and mortality. The majority of the world's population lives in countries where overweight and obesity claim more lives than underweight. Malnutrition is a problem faced by some communities due to political, economic, and social conditions. Iraq is one of the countries that has undergone significant changes on political and security levels, which has had a significant impact on the social and health aspects. Therefore, we conducted a study on the nutritional status of Iraqi children in 2018. We used classification techniques to determine the nutritional status categories for children, and classification techniques are widely used in many applied fields. [3]

Due to the significance of the topic, numerous researchers have conducted studies on it. For instance, in a study by (Mohammed, 2011), children in Iraq under the age of 6 were classified based on their nutritional status using data from 2006. The researcher utilized the Body Mass Index (BMI) as an indicator for classification. The study relied on data from the Multiple Indicator Cluster Survey (MICS) conducted in 2006. The results indicated that both the governorate (province) and gender influence the child's nutritional status, while the place of residence does not have an impact on the nutritional status. [4] In another study by (Balkiah et al., 2018), a comparison was made between the results of underweight prevalence using the Body Mass Index (BMI) method and the Fuzzy Logic approach, specifically employing the Mamdani method. Data on the weight and height of children were collected from three preschools in Paris. The results showed that the Mamdani method was highly effective compared to the BMI method due to its flexibility in controlling outputs, which is a crucial aspect of control systems despite the wide range of inputs. [5] (Permatasari, 2017) classified the nutritional status of children using a Fuzzy Inference System (FIS). The Mamdani method was applied, and nine rules were derived to determine the nutritional status. [6] In (Mohammed, 2020) assessed the nutritional status of children under 5 years old in Iraq for the year 2018. A comparison with the results from 2006 indicated an improvement in the nutritional status of children. [7] (Irmalia, 2022) developed a system that automatically determines the value and category of the Body Mass Index (BMI) using fuzzy logic to maintain nutritional status. The BMI index was evaluated with five attributes (Very Low, Low, Normal, High, Obese), and the results were consistent with manual calculations [8] (Hussein & Mohammad, 2023) build a fuzzy classification system for classifying the nutritional status of children under 5 years old in Iraq using the Mamdani method based on input variables such as weight and height to determine the nutritional status of the child. [9]

Our study focuses on the demographic of children under the age of five, which is a significant segment within society. These children are considered the nucleus of the community, as they play a vital role that will shape the society's future. The classification of children under the age of five to determine each child's precise category or class is crucial. To achieve this, we utilized fuzzy classification techniques, using two fuzzy methods, to classify children in Iraq based on their nutritional status. This classification aims to establish clear boundaries and distinctions among different nutritional categories, specifically identifying those who are experiencing malnutrition.

In this research, we apply two fuzzy classification methods (Mamdani and Sugeno) to classify children under the age of five in Iraq based on their nutritional status. We rely on linguistic variables such as weight and height as input variables, while the classification categories (outputs) are represented by the Body Mass Index (BMI) indicator. We then compare the results of each classification method with the conventional classification used in healthcare centers in Iraq. We use the accuracy of classification as the standard to determine the best-performing method among those used. This study aims to enhance the accuracy of classifying children's nutritional status using fuzzy classification methods and assess their effectiveness compared to the traditional classification approach.

2- Material and Methods

2.1 Fuzzy Set Theory

The definition of crisp sets is that they are a collection of elements, and any element can either belong or not belong to the set. The set is finite and not infinite. [10]

To represent linguistic variables and uncertain attributes, Zadeh introduced the concept of fuzzy sets. Fuzzy sets differ from crisp sets in that they allow an element to have partial membership in the set. This means that an element can partially belong to a fuzzy set, rather than belong or does not belong in classical sets. This characteristic of fuzzy sets enables a more flexible and nuanced representation of uncertainty. [11] Indeed, the theory of fuzzy sets is an extension of the classical set theory. The classical set theory can be considered as a special case of fuzzy sets where the degree of membership of its elements is either 0 or 1. [12]

The general formula for representing Fuzzy Sets is in the form of ordered pairs, where the first element represents the item in the set and the second element represents the degree of membership of that item to the set. [13]

$$A = \{x, M_A(x)\} \quad (1)$$

2.2 Fuzzy Classification Methods

The Classification is process of grouping data into specific and available categories. Statistical classification is a statistical procedure in which specific data is distributed into different groups based on quantitative information derived from more than one key attribute available in specific elements of this data. [3] There are several methods of classification that can be used, including the following classification methods:

1- Mamdani Method

This method is the most commonly used in decision-making using fuzzy logic and was introduced by Ebrahim Mamdani in 1975. [11] The steps are as follows:

Step1: fuzzification

Fuzzification is the process of converting crisp input values into a set of fuzzy inputs through membership functions for the sharp inputs. Their membership values are constrained between zero and one {0, 1} in the corresponding fuzzy sets. [14]

Step2: Creating fuzzy rules

Fuzzy rules are a set of linguistic statements that describe how decisions should be made regarding input classification or output control. It is necessary to consider all the possible combinations of inputs to establish these rules. [15] We define all the fuzzy rules based on the IF-THEN principle, where the IF part consists of inputs linked by the 'and' connector, and the outputs follow the then statement. [16]

$$F\ (X\ is\ A)\ and\ (Y\ is\ B)\ \ then\ (Z\ is\ c).$$

Step3: Aggregate results for all outputs

The fusion of outputs is performed in each case by applying the fuzzy implication operator. A fuzzy rule consists of two parts: the IF part, which involves multiple conditions and uses the 'and' connector, representing fuzzy intersection. The minimum operator $min(\mu_A(x), \mu_B(x))$ is used in the case of single observation, producing the same result or inference for the fuzzy rule. In the case of the 'or' connector, representing fuzzy union, the maximum operator $Max(\mu_A(x), \mu_B(x))$ is used. [17]

Step4: Defuzzification

Defuzzification is the process of converting fuzzy numbers (outputs) into crisp values. [13] In the Mamdani method, the center of mass method is utilized for defuzzification, relying on the center of mass of the fuzzy set. [18] This is done according to the following equation:

$$z = \frac{\sum_{j=1}^{n} z_j \mu(z_j)}{\sum_{j=1}^{n} \mu(z_j)} \qquad (2)$$

Where z represents the final output after defuzzification.

$\mu(z_j)$is the membership value of z_j to the fuzzy set or category.

2- Takagi–Sugeno–Kang (TSK) Method

This method was introduced by the Japanese researchers Tomohiro Takagi, Michio Sugeno, and Kang in 1985, and it can be summarized in the following steps: The first and second steps are the same as in the Mamdani method

Step3: Aggregate results for all outputs

In this step, the outputs are merged in the IF part of the fuzzy rule that uses the 'and' connector, representing fuzzy intersection. The minimum operator $min(\mu_A(x), \mu_B(x))$is used in the case of single observation, giving the same inference for the fuzzy rule. The difference between the sum of membership values or more is calculated, and the product of the same membership values or more is multiplied: $Product(\mu_A(x) + \mu_B(x) - \mu_A(x).\mu_B(x))$ [19]

Step4: Defuzzification

In this step, the Average Weighted Method is used to achieve a clear and crisp final result. This is done according to the following equation: [16]

$$z = \sum_{j=1}^{n} \frac{\mu(z_j)\ Z_j}{\mu(z_j)} \qquad (3)$$

Where z: represents the final output after defuzzification.

$\mu(z_j)$: is the membership value of zj to the fuzzy set or category.
Figure (1) the steps involved in the two classification methods Mamdani and Sugeno. [6]

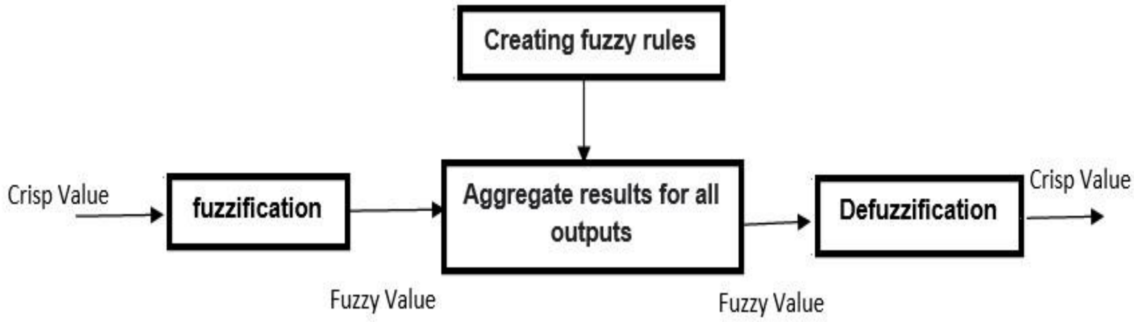

Figure -1. the steps of methods Mamdani and Sugeno.

2.3 The level of Classification Accuracy

After obtaining all the results from the classification methods, they are compared with the standard assessment of nutritional status established by the World Health Organization (WHO) to determine the level of accuracy. The accuracy level of any applied fuzzy classification method for determining nutritional status is calculated as follows: [6]

$$\text{Accuracy } level = \frac{Total\ \ of\ correct\ data}{Total\ data} \times 100\% \tag{4}$$

3- Case Study

The practical aspect focuses on classifying children in Iraq under the age of 5 Years according to nutritional status, using two fuzzy classification methods (Mamdani and Sugeno), while comparing these methods. This is based on data obtained from the Multiple Indicator Cluster Survey 6 (MICS6) conducted by the Central Statistical Organization in Iraq in 2018. Data was collected from 16,689 children under the age of 5 Years.

Table (1) shows the data divided into (12) age groups according to the age variable. [9] The variables studied to classify the nutritional status are the weight of the child as a linguistic variable and symbolized by the symbol (X) and its linguistic limits (x_1 Scrawny, x_2 Light, x_3 normal, x_4 Obese, x_5 very Obese), and the variable of child height as a linguistic variable and symbolizes it By the symbol (Y) and its categorical boundaries (y_1 Stunting, y_2 short, y_3 normal, y_4 tall, y_5 very tall) (input variables) and classification categories BMI and its categorical boundaries (Z_1 malnutrition, Z_2 underweight, Z_3 normal, Z_4 is overweight, Z_5 is obese) (Output variable).

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Table 1- It represents a description of the 2018 Iraq Children data.

Set	*Age*	*Female*	*Male*	*Sum*
Set1	Less than 2 Months	228	239	467
Set2	Less than 4 Months	296	320	616
Set3	Less than 6 Months	314	272	586
Set4	Less than 8 Months	268	292	560
Set5	Less than 10 Months	268	292	560
Set6	Less than 12 Months	203	247	450
Set7	Less than 16 Months	554	546	1100
Set8	Less than 20 Months	524	579	1103
Set9	Less than 24 Months	477	507	984
Set10	Less than 3 years	1498	1610	3108
Set11	Less than 4 years	1786	1809	3595
Set12	Less than 5 years	1644	1714	3358
	Sum	8060	8427	16487

The application of methods for classifying the nutritional status of children involves four main sequential steps, utilizing the R programming language through the 'frbs' package. These steps are as follows:

Step1: fuzzification

The construction of membership functions is based on the age categories in Table (1). Data (inputs) is fuzzified using triangular membership function, L function, and R function. In our current study, the parameters of the membership functions will be selected based on tables from the World Health Organization (WHO). [20] The fuzzification functions for variable Y, for the age category of females under two months, are as follows:

$$\mu_A y_1 (y;\ 49.8, 51.7) = \begin{cases} 1 & y \le 49.8 \\ \dfrac{51.7 - y}{51.7 - 49.8} & 49.8 \le y \le 51.7 \\ 0 & y \ge 51.7 \end{cases} \tag{5}$$

$$\mu_A y_2 (y;\ 49.8, 51.7, 53.7) = \begin{cases} 0 & y \le 49.8 \\ \dfrac{y - 49.8}{51.7 - 49.8} & 49.8 \le y \le 51.7 \\ \dfrac{53.7 - y}{53.7 - 51.7} & 51.7 \le y \le 53.7 \\ 0 & y \ge 53.7 \end{cases} \tag{6}$$

$$\mu_A y_3 (y;\ 51.7, 53.7, 55.6) = \begin{cases} 0 & y \le 51.7 \\ \dfrac{y - 51.7}{53.7 - 51.7} & 51.7 \le y \le 53.7 \\ \dfrac{55.6 - y}{55.6 - 53.7} & 53.7 \le y \le 55.6 \\ 0 & y \ge 55.6 \end{cases} \tag{7}$$

$$\mu_A y_4(y; 53.7, 55.6, 57.6) = \begin{cases} 0 & y \le 53.7 \\ \dfrac{y - 53.7}{55.6 - 53.7} & 53.7 \le y \le 55.6 \\ \dfrac{57.6 - y}{57.6 - 55.6} & 55.6 \le y \le 57.6 \\ 0 & y \ge 57.6 \end{cases} \tag{8}$$

$$\mu_A y_5(y; 55.6, 57.6) = \begin{cases} 0 & y \le 55.6 \\ \dfrac{y - 55.6}{57.6 - 55.6} & 55.6 \le y \le 57.6 \\ 1 & y \ge 57.6 \end{cases} \tag{9}$$

Figure (2) represents the function of belonging to the variable of height according to the data of the nutritional status of Iraqi children females of less than two months of age:

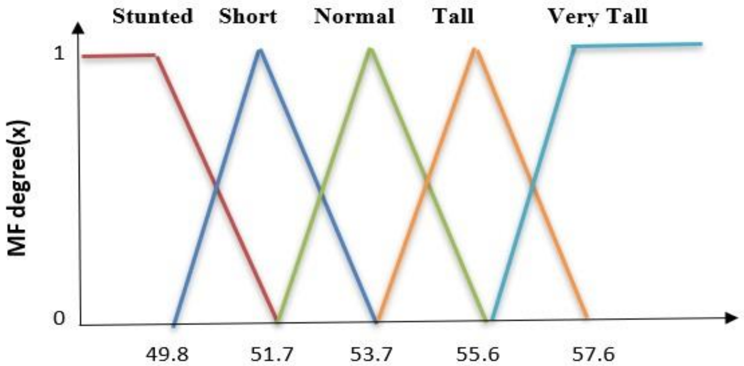

Figure -2 Represents the affiliation functions of the length variable.

Where the vertical axis is the degree of belonging to the input value of the length variable, while, the horizontal axis is the input value that is the length variable, and in order to apply fuzzy functions to the X variable for the age group less than two months for females, the following:

$$\mu_A \mathbf{x}_1(x; 3.2, 3.6) = \begin{cases} 1 & x \le 3.2 \\ \dfrac{3.6 - x}{3.6 - 3.2} & 3.2 \le x \le 3.6 \\ 0 & x \ge 3.6 \end{cases} \tag{10}$$

$$\mu_A \mathbf{x}_2(x; 3.2, 3.6, 4.2) = \begin{cases} 0 & x \le 3.2 \\ \dfrac{x - 3.2}{3.6 - 3.2} & 3.2 \le x \le 3.6 \\ \dfrac{4.2 - x}{4.2 - 3.6} & 3.6 \le x \le 4.2 \\ 0 & x \ge 4.2 \end{cases} \tag{11}$$

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$$\mu_A x_3(x;3.6,4.2,4.8)=\begin{cases}0 & x \le 3.6\\ \dfrac{x-3.6}{4.2-3.6} & 3.6 \le x \le 4.2\\ \dfrac{4.8-x}{4.8-4.2} & 4.2 \le x \le 4.8\\ 0 & x \ge 4.8\end{cases} \quad (13)$$

$$\mu_A x_4(x;4.2,4.8,5.5)=\begin{cases}0 & x \le 4.2\\ \dfrac{x-4.2}{4.8-4.2} & 4.2 \le x \le 4.8\\ \dfrac{5.5-x}{5.5-4.8} & 4.8 \le x \le 5.5\\ 0 & x \ge 5.5\end{cases} \quad (14)$$

$$\mu_A x_5(x;4.8,5.5)=\begin{cases}0 & x \le 4.8\\ \dfrac{x-4.8}{5.5-4.8} & 4.8 \le x \le 5.5\\ 1 & x \ge 5.5\end{cases} \quad (15)$$

Figure (3) represents the function of belonging to the weight variable according to the nutritional status data of children females in Iraq for less than two months of age:

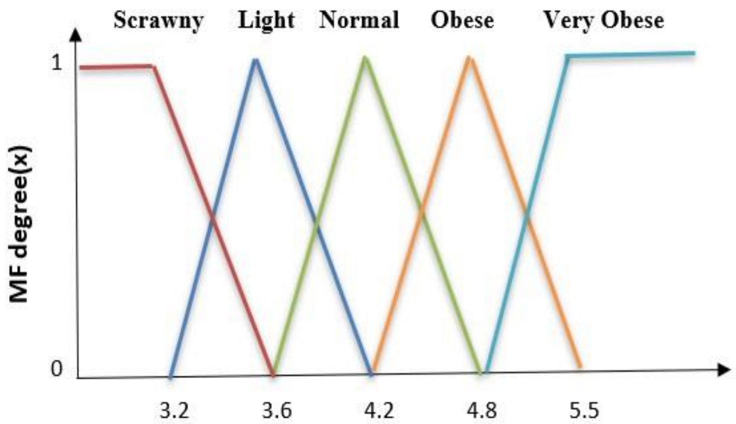

Figure -3 Represents the affiliation functions of the weight variable.

Where the vertical axis is the degree of belonging to the input value of the weight variable while, the horizontal axis is the input value that is the weight variable, in the same way the rest of the age groups, females and males, are fuzzed based on the tables of the World Health Organization [9].

Step2: Fuzzy Rules

Fuzzy rules are established in the fuzzy classification methods (Mamdani and Sugeno) by considering all the possible combinations of inputs, based on the information provided in Table (2). A total of 25 fuzzy rules were deduced for classifying the nutritional status of all age categories, both for males and females.

Table 2- illustrates the fuzzy rules for classifying the nutritional status of children.

Height(cm)		Weight (kg)				
		Scrawny	**Light**	**Normal**	**Obese**	**Very Obese**
	Stunted	Underweight	Normal	Obesity	Obesity	Obesity
	Short	Malnutrition	Underweight	Overweight	Obesity	Obesity
	Normal	Malnutrition	Underweight	Normal	Overweight	Obesity
	Tall	Malnutrition	Malnutrition	Underweight	Overweight	Obesity
	Very Tall	Malnutrition	Malnutrition	Underweight	Normal	Overweight

From Table (2), the following rules were deduced:

$R1: if\ \ X\ \ is\ x_1\ and\ Y\ \ \ is\ y_1 then\ \ Z\ \ is\ z_2$

$R2: if\ \ X\ \ is\ x_1\ and\ Y\ \ \ is\ y_2 then\ \ Z\ \ is\ z_1$

$\vdots$

$R25: if\ \ X\ \ is\ x_5\ and\ Y\ \ \ is\ y_5 then\ \ Z\ \ is\ z_4$

Step3: Aggregate results and Defuzzification

After obtaining the fuzzy rules, the next step involves aggregating the results for all the outputs and performing the process of defuzzification according to each fuzzy classification method This process is carried out to classify each child among Iraq's children based on their nutritional status Furthermore, a comparison is made between the results of each method and the classical classification. This is done to calculate the number of accurate cases and apply the classification accuracy level criterion for each method, as per Equation (4). Table (3) illustrates the weight, height, and body mass index (BMI) of each child within the age category of less than two months, specifically for males. It also presents the classification results for each child using the classical classification method, as well as the Mamdani and Sugeno fuzzy methods. A comparison is made between the outcome of each observation and the classical classification to determine the number of correct cases. This process is then repeated for the remaining age categories, for both males and females.

Table 3- Nutritional Status Classification Results for Iraqi Female Children in the Age Category Less than 2 Months

S.	*Y*	*X*	*Classification Classical*	*Mamdani*	*Comparison*	*Sugeno*	*Comparison*
1	36.0	3.9	Z_5	Z5	TRUE	Z4	FALSE
2	37.0	5.6	Z_5	Z5	TRUE	Z5	TRUE
3	47.6	3.9	Z_4	Z5	FALSE	Z4	TRUE
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮
226	56.6	4.4	Z_3	Z4	FALSE	Z3	TRUE
227	50.6	3.1	Z_2	Z2	TRUE	Z2	TRUE
228	49.9	2.8	Z_1	Z2	FALSE	Z2	FALSE

4- Results and Discussion

After applying the fuzzy classification methods (Mamdani and Sugeno) for all age groups, genders, and categories as shown in Table (4), the results regarding the numbers and percentages of children in each nutritional status category were obtained, Table (7, 6, 5, 4) illustrates the number of classified children according to their nutritional status for both females and males across all age groups.

Table 4- presents the number of children classified according to nutritional status by age groups for females.

Age	*Malnutrition*		*Underweight*		*Normal*		*Overweight*		*Obesity*	
	N	Per %	N	Per %	N	Per %	N	Per %	N	Per %
Less than 2 Months	15	6.6	57	25.0	45	19.7	74	32.5	37	16.2
Less than 4 Months	33	11.1	120	40.5	68	32.0	54	18.2	21	7.1
Less than 6 Months	17	5.4	112	35.7	69	22.0	89	28.3	27	8.6
Less than 8 Months	17	6.3	67	25.0	67	25.0	82	30.6	35	13.1
Less than 10 Months	14	5.2	67	25.0	65	24.3	79	29.5	43	16.0
Less than 12 Months	4	2.0	40	19.7	43	21.2	87	42.9	29	14.3
Less than 16 Months	6	1.1	106	19.1	131	23.6	176	31.8	135	24.4
Less than 20 Months	9	1.7	76	14.5	136	26.0	151	28.8	152	29.0
Less than 24 Months	7	1.5	103	21.6	129	27.0	131	27.5	107	22.4
Less than 3 years	14	0.9	448	29.9	469	31.3	272	18.2	295	19.7
Less than 4 years	22	1.2	527	29.5	613	34.3	383	21.4	241	13.5
Less than 5 years	29	1.8	564	34.3	535	32.5	325	19.8	191	11.6

From Table (4), it is evident that female infants in the age group less than two months were classified according to nutritional status as follows: 15 infants (6.6%) were categorized under malnutrition, 57 infants (25%) under underweight, 45 infants (19.7%) under normal weight, 74 infants (32.5%) under overweight, and 37 infants (16.2%) under obesity. Similar categorizations were made for the rest of the age groups for females using the Mamdani method.

Table 5- presents the numbers of children classified according to nutritional status by age groups for males

Age	*Malnutrition*		*Underweight*		*Normal*		*Overweight*		*Obesity*	
	N	Per %	N	Per %	N	Per %	N	Per %	N	Per %
Less than 2 Months	13	5.4	70	29.3	54	22.6	75	31.4	27	11.3
Less than 4 Months	31	9.7	133	41.6	79	24.7	52	16.3	25	7.8
Less than 6 Months	26	9.6	103	37.9	56	20.6	63	23.2	24	8.8
Less than 8 Months	13	4.5	88	30.1	62	21.2	88	30.1	41	14.0
Less than 10 Months	14	4.8	74	25.3	65	22.3	95	32.5	44	15.1
Less than 12 Months	8	3.2	54	21.9	56	22.7	87	35.2	42	17.0
Less than 16 Months	20	3.7	116	21.2	139	25.5	144	26.4	127	23.3
Less than 20 Months	6	1.0	112	19.3	146	25.2	166	28.7	149	25.7
Less than 24 Months	10	2.0	103	20.3	131	25.8	151	29.8	112	22.1

Less than 3 years	18	1.1	457	28.4	532	33.0	298	18.5	305	18.9
Less than 4 years	27	1.5	486	26.9	660	36.5	397	21.9	239	13.2
Less than 5 years	24	1.4	512	29.9	560	32.7	396	23.1	222	13.0

From Table. (5) illustrates the numbers of male children classified according to nutritional status for all age groups using the Mamdani method. The table reveals that for male children in the age group under two months, they were categorized as follows: 13 children (5.4%) were classified as malnutrition, 70 children (29.3%) as underweight, 54 children (22.6%) as normal weight, 75 children (31.4%) as overweight, and 27 children (11.3%) as obese. This pattern extends to the remaining age groups for males according to the Mamdani method.

Furthermore, Table. (6) displays the numbers of male children classified according to nutritional status for all age groups using the Sugeno method. The table indicates that for children in the age group under two months, they were classified as follows: 18 children (7.5%) were categorized as malnutrition, 65 children (27.2%) as underweight, 77 children (32.2%) as normal weight, 59 children (24.7%) as overweight, and 20 children (8.4%) as obese. This trend continues for the remaining age groups for males according to the Sugeno method.

Table 6- presents the number of children classified according to nutritional status by age groups for males.

Age	***Malnutrition***		***Underweight***		***Normal***		***Overweight***		***Obesity***	
	N	Per %	N	Per %	N	Per %	N	Per %	N	Per %
Less than 2 Months	18	7.5	65	27.2	77	32.2	59	24.7	20	8.4
Less than 4 Months	44	13.8	137	42.8	88	27.5	38	11.9	13	4.1
Less than 6 Months	34	12.5	104	38.2	71	26.1	51	18.8	12	4.4
Less than 8 Months	23	7.9	81	27.7	87	29.8	81	27.7	20	6.8
Less than 10 Months	22	7.5	75	25.7	86	29.5	83	28.4	26	8.9
Less than 12 Months	13	5.3	55	22.3	76	30.8	75	30.4	28	11.3
Less than 16 Months	26	4.8	130	23.8	150	27.5	159	29.1	81	14.8
Less than 20 Months	11	1.9	108	18.7	178	30.7	181	31.3	101	17.4
Less than 24 Months	13	2.6	112	22.1	162	32.0	142	28.0	78	15.4
Less than 3 years	26	1.6	479	29.8	576	35.8	379	23.5	150	9.3
Less than 4 years	40	2.2	580	32.1	667	36.9	415	22.9	107	5.9
Less than 5 years	32	1.9	557	32.5	682	39.8	342	20.0	101	5.9

From Table 7, it is evident that female infants in the age group under two months were classified based on nutritional status as follows: 16 infants (7%) categorized as malnutrition, 60 infants (26.3%) as underweight, 70 infants (30.7%) as normal weight, 57 infants (25%) as overweight, and 25 infants (11%) as obese. This trend continues for the remaining age groups for females according to the Sugeno method.

Table 7- presents the number of children classified according to nutritional status by age groups for females.

Age	*Malnutrition*		*Underweight*		*Normal*		*Overweight*		*Obesity*	
	N	Per %	N	Per %	N	Per %	N	Per %	N	Per %
Less than 2 Months	16	7.0	60	26.3	70	30.7	57	25.0	25	11.0
Less than 4 Months	40	13.5	120	40.5	75	25.3	48	16.2	13	4.4
Less than 6 Months	26	8.3	115	36.6	100	31.8	53	16.9	20	6.4
Less than 8 Months	19	7.1	59	22.0	97	36.2	68	25.4	25	9.3
Less than 10 Months	18	6.7	68	25.4	88	32.8	66	24.6	28	10.4
Less than 12 Months	5	2.5	37	18.2	76	37.4	65	32.0	20	9.9
Less than 16 Months	15	2.7	104	18.8	172	31.0	174	31.4	89	16.1
Less than 20 Months	10	1.9	88	16.8	160	30.5	172	32.8	94	17.9
Less than 24 Months	11	2.3	105	22.0	159	33.3	135	28.3	67	14.0
Less than 3 years	18	1.2	470	31.4	520	34.7	348	23.2	142	9.5
Less than 4 years	24	1.3	584	32.7	693	38.8	365	20.4	120	6.7
Less than 5 years	39	2.4	630	38.3	616	37.5	272	16.5	87	5.3

5- The Accuracy of Classification Level

After applying the classification methods (Mamdani method, Sugeno method) and obtaining the results for classifying each child in all age groups, for both males and females, and calculating the number of correct cases for each classification method in all age groups and genders, the accuracy level criterion is applied for each method. Table 8 presents the results of the classification accuracy criterion for each of the classification methods across all age groups and for both males and females.

Table 8- Results of the Classification Accuracy Criterion for All Age Groups Males and Females.

Age	*Sugeno*		*Mamdani*	
	Female%	**Male%**	**Female%**	**Male%**
Less than 2 Months	65.4	60.7	50.0	45.2
Less than 4 Months	62.8	62.2	57.1	55.0
Less than 6 Months	62.7	58.5	51.3	48.9
Less than 8 Months	64.6	63.4	49.6	47.9
Less than 10 Months	58.6	60.6	44.4	47.9
Less than 12 Months	62.6	56.7	42.4	47.0
Less than 16 Months	61.9	57.5	47.3	48.0
Less than 20 Months	59.9	64.8	46.9	50.8
Less than 24 Months	60.0	62.3	48.2	49.7
Less than 3 years	56.0	56.9	42.5	42.4
Less than 4 years	57.3	57.8	45.6	49.1
Less than 5 years	56.1	59.6	47.0	48.0

The results from Table No. (8) indicate that the highest accuracy percentages in the classification accuracy criterion are achieved by the Sugeno method for all age groups, both males and females. This suggests that the Sugeno method is the most effective approach among the two methods used.

6- Conclusion

It is possible to utilize fuzzy classification using two different methods (Mamdani method, Sugeno method) to classify the nutritional status of Iraqi children under the age of five based on the input variables and employing fuzzy logic. Through these two methods 25 fuzzy rules were derived to determine the category or class for each child under five years of age.
Upon comparing the two methods it becomes evident that the Sugeno method is the most effective, according to the employed classification accuracy criterion, achieving an accuracy rate of approximately 60% for various age categories, both for males and females. On the other hand, the Mamdani method yielded accuracy rates ranging between 50% and 40%.
It was deduced that infants from birth up to 8 months old are most affected by underweight, while children between 8 months and 24 months old experience weight gain. The results also indicated that the majority of children aged 3 to 5 years fall within the normal weight range. Using fuzzy classification instead of classical classification in health centers in Iraq aims to achieve more accurate classification results for children.

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