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Diagnosis Of Familial Mediterranean Fever (FMF) With Fuzzy Logic

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Familial mediterranean fever disease,
Fuzzy evaluation,
Fuzzy inference,
Fuzzy logic

Abstract — In this work, we developed a fuzzy decision-making method to help diagnose of Familial Mediterranean Fever (FMF), with the support of a doctor who is an expert in the field, and we briefly called it the FMF fuzzy diagnosis method (FMF-FDM). In the decision-making mechanism, we used the Mamdani method, which is one of the fuzzy logic inference methods.

Subject Classification (2020): 34KXX, 39AXX.

1. Introduction

Fuzzy logic is a mathematical framework for dealing with uncertainty and imprecision. It was introduced by Lotfi Zadeh (1965) as an extension of classical logic, which relies on binary true/false values. Fuzzy logic is particularly useful in situations where information is vague, uncertain, or incomplete. In classical logic, a statement is either true or false. However, in the real world, many situations are not black and white, and there may be degrees of truth or membership. Fuzzy logic allows for the representation of partial truth values, expressed as degrees of membership in a set. This is accomplished through the use of linguistic variables and fuzzy sets. For more detailed information about fuzzy logic, fuzzy sets and their applications, we refer to [2], [7], [12] and [23].

When solving problems that are based on fuzzy sets and involve uncertainty in practice, there are many fuzzy inference methods used in the decision-making stage. Prominent among these are; Mamdani [9], Larsen [8], TSK [16], Tsukamoto [19] methods. Here we will use the Mamdani inference method, which is the most widely used because it is easy to model and interpret. Unlike other inference methods, In Mamdani inference, the max-min method is used to obtain fuzzy output values from fuzzy inputs and the centroid method is used to clarify fuzzy output values. Mamdani inference is a method that is close to human perception, requires expert knowledge, is relatively easy to design, and can be adapted to many problems.

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Fuzzy inference methods, it is used in areas such as risk analysis, marketing strategies, economic decisions, medical diagnoses and technological applications. Today as in other fields, in the field of medicine, fuzzy logic-based decision-making systems are used in the diagnosis of many diseases. Some of these studies that will help doctors in diagnosis and treatment;[21] detection of types of thyroid disease; [18], diagnosis of coronary heart disease;[20], determining the level of iron deficiency anemia; [17], Determination of Thalassemia disease; [3], diagnosis of prostate cancer;[24], A new type of soft covering based rough sets applied to multicriteria group decision making for medical diagnosis;[25], N-soft mappings with application in medical diagnosis,[26];Studies on purine-pyrimidine fluctuations and DNA sequencing of Familial Mediterranean Fever (FMF) disease can be given as examples.

FMF; self-limiting disease characterized by recurrent fever, peritonitis, pleuritis, arthritis, or erysipelas-like skin manifestations, it is an autoinflammatory disease of ethnic origin that is inherited in an autosomal recessive manner [1]. Despite developments, there is no specific laboratory test that can be used for FMF disease. Complaints for this, Diagnosis is made by taking into consideration family history, guiding laboratory tests such as acute phase reactants, presence of genetic mutation, and regression of complaints with colchicine treatment. Acute phase reactants that change secondary to inflammation are clinically supportive but specific tests. The increase in white blood cell count (WBC), erythrocyte sedimentation rate (ESR), C-reactive protein (CRP), serum amyloid A(SAA), fibrinogen, which are positive acute phase reactants, during the attack and decreasing to normal values within a few days following the end of the attack is highly significant in the presence of clinical compatibility [15] for this reason, diagnostic criteria, various scoring and algorithm methods are created. Tel-Hashomer Criteria; the most commonly used FMF diagnostic criteria today (Table1).

Table 1.1. Tel-Hashomer Criteria

Major Criteria	Minor Criteria
Recurrent febrile episodes accompanied by peritonitis, pleuritis or synovitis	Recurrent febrile attacks
Type AA amyloidosis without predisposing disease	Erysipelas-like erythema
Significant response to colchicine treatment	History of FMF in first-degree relatives

Definitive diagnosis: 2 major or 1 major + 2 minor criteria, Possible diagnosis: 1 major + 1 minor criteria

In this study, we also blood count results determined with the help of a specialist physician for the diagnosis of FMF and a decision-making system will be created to contribute to doctors in the process of disease detection by using the disease history questionnaire and the fuzzy logic method. This study is part of the Master's Thesis of Gülender [4].

2. FMF Fuzzy Diagnosis Method (FMF-FDM)

In this section, we will develop a fuzzy decision-making method that will help diagnose FMF disease with the help of fuzzy logic. We will briefly call this the FMF-FDM.

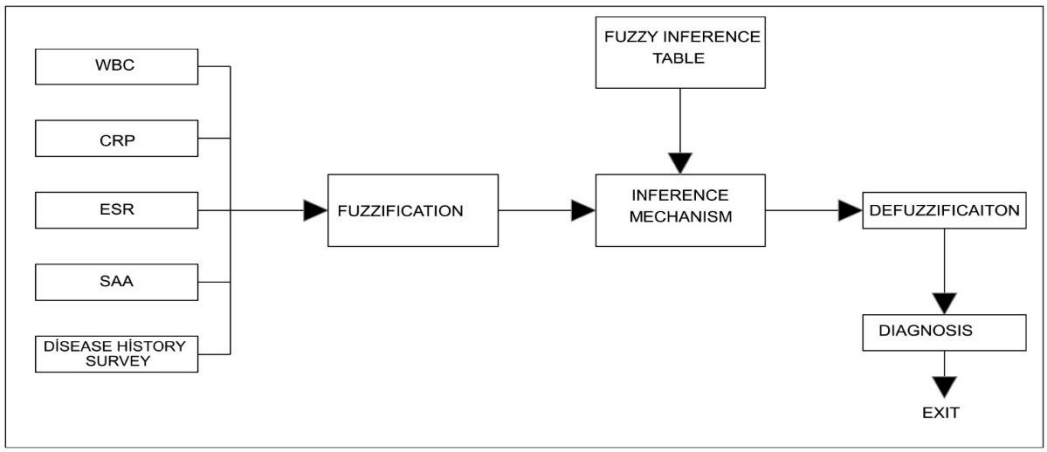

Figure 2.1. FMF-FDM Schema

As seen in the FMF-FDM diagram in Figure 2.1, the system consists of 5 input parameters and 1 output. Entries; WBC, CRP, ESR, SAA blood count and disease history survey results. Decision makers based on fuzzy logic; Structurally, it consists of fuzzification, rule-based inference mechanism and defuzzification units. Accordingly, in FMF-FDM, first the verbal values and numerical ranges of the input and output parameters will be determined and fuzzification. Later, a rule base will be created with the help of a specialist physician. Finally, the fuzzy output values will be defuzzification using the Mamdani inference method.

2.1. Fuzzification

In this section, we will write fuzzy sets expressing the "high", "normal" and "low" verbal values of each parameter to fuzz the FMF-FDM input parameters. Every fuzzy set is defined by a membership function. The membership function μ of each fuzzy set is different and these are

$$\mu: E \rightarrow [0,1]$$

They are functions defined on the interval [0,1] in a universal set E determined by experts.

2.1.1. Determining Value Ranges of Parameters

Here, as the universal set of membership functions of fuzzy sets that will express the parameters, The value ranges given in Table 2.1 for input parameters and Table 2.2 for output parameter used by specialist physicians in Tokat Gaziosmanpaşa University Faculty of Medicine, Department of Rheumatology will be taken.

Table 2.1. Membership value ranges of input parameters

WCB (10^3/ml)	
High	> 7
Normal	4-10
Low	7 <
CRP (mg/l)	
High	> 5
Normal	2-8
Low	< 5
ESR (mm/s)	
High	> 20
Normal	10-30
Low	< 20

SAA(mg/dl)	
High	> 7
Normal	4-10
Low	< 7
DISEASE HISTORY SURVEY (Piece)	
High	> 5
Normal	3- 7
Low	<5

Table 2.2. Membership value ranges of the output parameter

FMF Level	
High FMF	> 60
Middle FMF	40-80
Low FMF	20-60
No FMF	< 40

2.1.2. Membership Functions and Graphics of Parameters

Here, first, the membership functions of the fuzzy sets that will express the "high", "normal" and "low" verbal values of the parameters will be graphed with the help of an expert physician at Tokat Gaziosmanpaşa University Faculty of Medicine, Department of Rheumatology, and then the membership functions expressing each graph will be written.

In fuzzy sets, “triangle”, “trapezoid”, “bell curve” etc. are used to determine the membership value of the elements. They use membership functions. Here, triangular membership functions will be used while fuzzification due to ease of use.

a) WBC

The graphs of the membership function of the fuzzy sets determined as "low", "normal" and "high" belonging to the WBC input parameter are drawn as in Figure 2.2.

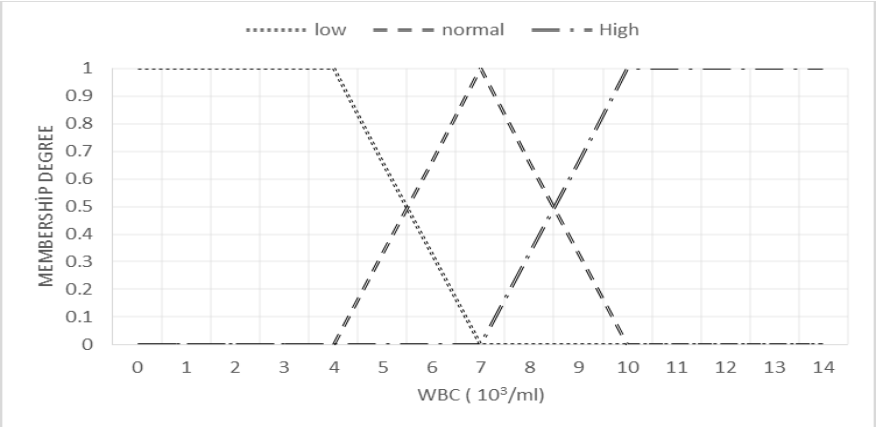

Figure 2.2. WBC membership function graph

In Figure 2.2 According to the WBC membership function graph, the expression of membership functions corresponding to the “low”, “normal” and “high” cluster, respectively, is obtained as follows.

$$\mu_{\text{low}}(x) = \begin{cases} 1, & x \leq 4 \\ (7-x)/3, & 4 \leq x \leq 7 \\ 0, & x > 7 \end{cases}$$

$$\mu_{\text{normal}}(x) = \begin{cases} 0, & x < 4 \text{ or } x > 10 \\ (x-4)/3, & 4 \leq x \leq 7 \\ (10-x)/3, & 7 \leq x \leq 10 \end{cases}$$

$$\mu_{\text{high}}(x) = \begin{cases} 0, & x < 7 \\ (x-7)/3, & 7 \leq x \leq 10 \\ 1, & x \geq 10 \end{cases}$$

b) CRP

The membership function graphs of the fuzzy sets determined as "low", "normal" and "high" belonging to the CRP input parameter are drawn as in Figure 2.3.

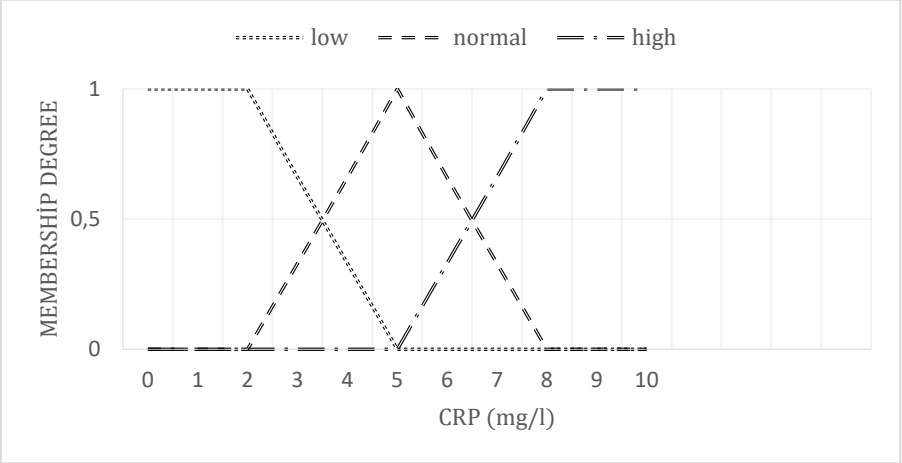

Figure 2.3. CRP membership function graph

In Figure 2.3 According to the CRP membership function graph, the expression of membership functions corresponding to the “low”, “normal” and “high” cluster, respectively, is obtained as follows.

$$\mu_{\text{low}}(x) = \begin{cases} 1, & x \leq 2 \\ (5-x)/3, & 2 \leq x \leq 5 \\ 0, & x > 5 \end{cases}$$

$$\mu_{\text{normal}}(x) = \begin{cases} 0, & x < 2 \text{ or } x > 8 \\ (x-2)/3, & 2 \leq x \leq 5 \\ (8-x)/3, & 5 \leq x \leq 8 \end{cases}$$

$$\mu_{\text{high}}(x) = \begin{cases} 0, & x < 5 \\ (x-5)/3, & 5 \leq x \leq 8 \\ 1, & x \geq 8 \end{cases}$$

c)ESR

The graphs of the membership function of the fuzzy sets determined as "low", "normal" and "high" belonging to the ESR input parameter are drawn as in Figure 2.4.

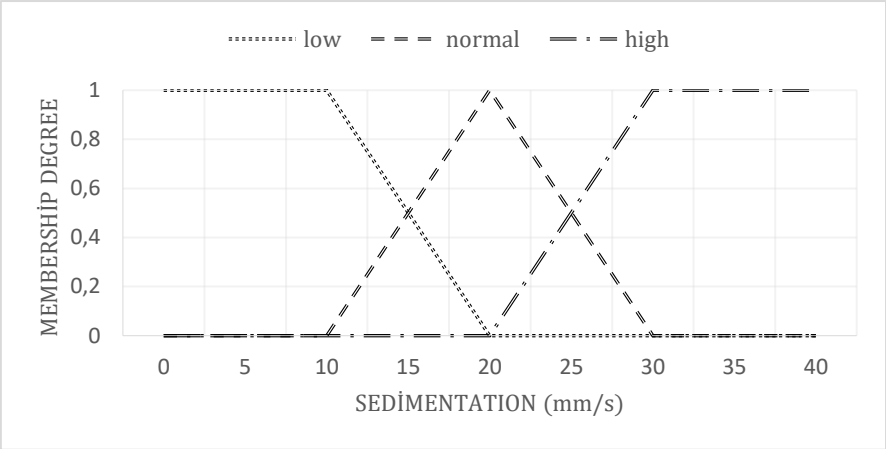

Figure 2.4. ESR membership function graph

In Figure 2.4 According to the ESR membership function graph, the expression of membership functions corresponding to the “low”, “normal” and “high” cluster, respectively, is obtained as follows.

$$\mu_{\mathbf{low}}(x) = \begin{cases} 1, & x \leq 10 \\ (20 - x)/10, & 10 \leq x \leq 20 \\ 0, & x > 20 \end{cases}$$

$$\mu_{\mathbf{normal}}(x) = \begin{cases} 0, & x < 10 \text{ or } x > 30 \\ (x - 10)/10, & 10 \leq x \leq 20 \\ (30 - x)/10, & 20 \leq x \leq 30 \end{cases}$$

$$\mu_{\mathbf{high}}(x) = \begin{cases} 0, & x < 20 \\ (x - 20)/10, & 20 \leq x \leq 30 \\ 1, & x \geq 30 \end{cases}$$

d) SAA

The graphs of the membership function of the fuzzy sets determined as "low", "normal" and "high" belonging to the SAA input parameter are drawn as in Figure 2.5.

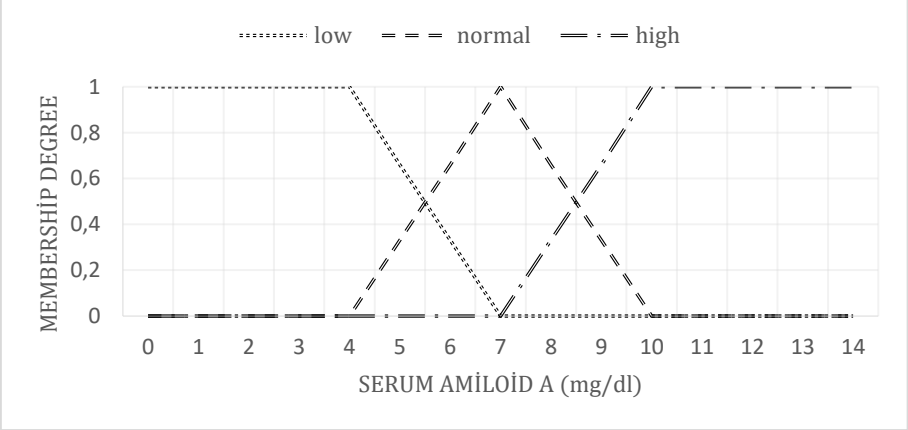

Figure 2.5. SAA membership function graph

According to the SAA membership function graph in Figure 2.5, the expression of the membership functions corresponding to the "low", "normal" and "high" fuzzy sets of the SAA input parameter is obtained as follows.

$$\mu_{\text{low}}(x) = \begin{cases} 1, & x \leq 4 \\ (7-x)/3, & 4 \leq x \leq 7 \\ 0, & x > 7 \end{cases}$$

$$\mu_{\text{normal}}(x) = \begin{cases} 0, & x < 4 \text{ or } x > 10 \\ (x-4)/3, & 4 \leq x \leq 7 \\ (10-x)/3, & 7 \leq x \leq 10 \end{cases}$$

$$\mu_{\text{high}}(x) = \begin{cases} 0, & x < 7 \\ (x-7)/3, & 7 \leq x \leq 10 \\ 1, & x \geq 10 \end{cases}$$

e) Disease History Survey

The disease history questionnaire created with the help of a specialist physician plays an important role in diagnosing the disease in the light of the patient's answers. The disease history questionnaire for FMF is provided below.

In the 10-question disease history survey prepared using the Likert scale, a value between 0 and 10 is obtained as a result of the disease history survey by giving 1 point for yes answers and 0 point for no answers.

Disease History Survey

Did the complaints start under the age of 20?
( ) Yes ( ) No
Do you have a fever above 38 degrees in the form of attacks that lasts 1-3 days and subsides on its own?
( ) Yes ( ) No
Do you have recurrent abdominal pain that lasts 6-72 hours and regresses spontaneously in the form of attacks?
( ) Yes ( ) No
Is there any recurrent chest pain that regresses spontaneously in the form of an attack and lasts 6-72 hours?
( ) Yes ( ) No
Are other causes excluded during attacks?
( ) Yes ( ) No
Do you have red arthritis that regresses spontaneously in the form of attacks and lasts 1-7 days?
( ) Yes ( ) No
Are there self-healing skin lesions with an average diameter of 10-15 cm, with sharply limited erythematous temperature increase, especially on the legs, in the form of an attack?
( ) Yes ( ) No
Do you have a history of appendectomy?
( ) Yes ( ) No
Does exercise trigger attacks?
( ) Yes ( ) No
Is there anyone in your family with FMF?
( ) Yes ( ) No

The graphs of the membership function of the fuzzy sets determined as "low", "normal" and "high" belonging to the input parameter of the disease history survey are drawn as in Figure 2.6.

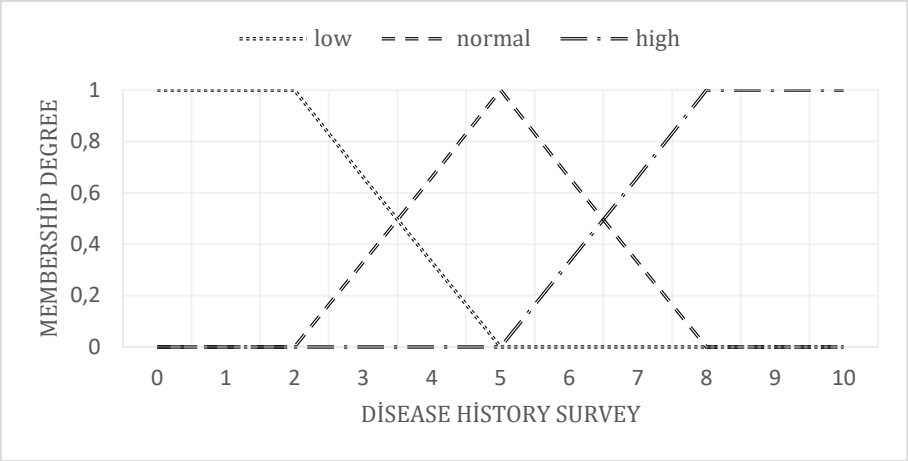

Figure 2.6. Disease history survey membership function graph

According to the membership function graph of the disease history survey in Figure 2.6, the expression of the membership functions corresponding to the "low", "normal" and "high" fuzzy sets of the input parameter of the disease history survey, respectively, is obtained as follows.

$$\mu_{\mathbf{low}}(x) = \begin{cases} 1, & x \leq 2 \\ (5-x)/3, & 2 \leq x \leq 5 \\ 0, & x > 5 \end{cases}$$

$$\mu_{\mathbf{normal}}(x) = \begin{cases} 0, & x < 2 \text{ or } x > 8 \\ (x-2)/3, & 2 \leq x \leq 5 \\ (8-x)/3, & 5 \leq x \leq 8 \end{cases}$$

$$\mu_{\mathbf{high}}(x) = \begin{cases} 0, & x < 5 \\ (x-5)/3, & 5 \leq x \leq 8 \\ 1, & x \geq 8 \end{cases}$$

2.2. Inference Rules

The 5 input parameters set for FMF diagnosis and each parameter's there are three fuzzy sets of verbal values, “low” “normal” “high”. In order to obtain a fuzzy output from these fuzzy sets, it will be determined with the help of a specialist physician

IF CRP is normal, WBC is low, ESR is high, SAA is high, and the disease history questionnaire is normal, the FMF level is medium.

Like $3\times3\times3\times3\times3 = 243$ the rule of inference occurs. Not every rule currently occurring in an inference system is used. Only the rules triggered by the input parameters are used. What we mean by triggering the rules here is that when we write instead the membership values of the verbal values in the rules, at least one of them is different from "0". In this case, the rule is triggered. The rule is not triggered when all values have a membership degree of “0”.

Fuzzy sets of output parameters are obtained from fuzzy sets representing input parameters with inference rules. The fuzzy set of the output parameter is used to make decisions in FMF diagnosis. On the part of the specialist physician, the universal set of the membership function of the fuzzy set of the output parameter was determined as the [0,100] range, and the level of FMF was defined with four different fuzzy sets: "no FMF", "low FMF", "middle FMF" and "high FMF". The membership functions of these fuzzy sets are drawn as in Figure 2.7.

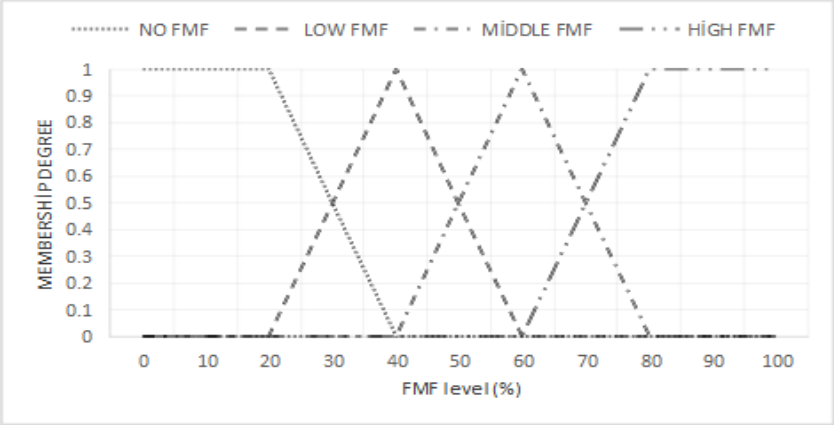

Figure 2.7. FMF level membership function graph

According to the FMF level membership function graph in Figure 2.7., the expression of the membership functions corresponding to the "no FMF", "low FMF", "middle FMF" and "high FMF" fuzzy sets of the FMF level output parameter is as follows, respectively.

$$\mu_{\text{no FMF}}(x) = \begin{cases} 1, & x \leq 20 \\ (40 - x)/20, & 20 \leq x \leq 40 \\ 0, & x > 40 \end{cases}$$

$$\mu_{\text{low FMF}}(x) = \begin{cases} 0, & x \leq 20 \text{ or } x \geq 60 \\ (x - 20)/20, & 20 \leq x \leq 40 \\ (60 - x)/20, & 40 \leq x \leq 60 \end{cases}$$

$$\mu_{\text{middle FMF}}(x) = \begin{cases} 0, & x \leq 40 \text{ or } x \geq 80 \\ (x - 40)/20, & 40 \leq x \leq 60 \\ (80 - x)/20, & 60 \leq x \leq 80 \end{cases}$$

$$\mu_{\text{high FMF}}(x) = \begin{cases} 0, & x \leq 60 \\ (x - 60)/20, & 60 \leq x \leq 80 \\ 1, & x \geq 80 \end{cases}$$

2.3. Defuzzification

The parts we have created so far are the knowledge base and rule base in the fuzzy system. Since the Mamdani inference method is used here, the verbal values representing fuzzy sets in our rule base are connected with the "AND" conjunction, so the minimum of the entries is taken for the membership degree of the membership function of the output of each rule. Then, the output values are obtained by taking the maximum of the minimum values obtained between the triggered rules.

Table 2.3. Disease inference table

FMF Level	FMF Gene Mutation	Conclusion
0-25	Positive	FMF patient. Since attacks that disrupt the routine of life are rare and return to normal in a short time, drug treatment is not recommended. Regular follow-up is recommended.
	Negative	Not a FMF patient. It needs to be re-evaluated during the attack.
25-50	Positive	FMF patient. Annual checkup is recommended.
	Negative	Not a FMF patient. It needs to be re-evaluated during the attack. If there is no attack, routine control is recommended every 6 months.
50-75	Positive	FMF patient. Colchicine (2*1) treatment should be started. Routine control is recommended every 3 months.
	Negative	FMF patient. Colchicine (2*1) treatment should be started. Routine control is recommended every 6 months.
75-100	Positive	FMF patient. Colchicine (3*1) treatment should be started. Clinical response to colchicine is to be expected.
	Negative	FMF patient. Colchicine (3*1) treatment should be started. Clinical response to colchicine is to be expected.

Defuzzification is the process of transforming the fuzzy sets obtained as a result of an applied inference method into real life language. Here, the data obtained from the fuzzy sets formed by the verbal values "no FMF", "low FMF", "middle FMF" and "high FMF", which express the level of FMF as the output parameter of FMF-FDM, it will be clarified and converted into a language that the patient can understand. With FMF-FDM, the doctor who will diagnose FMF uses two data. These; The patient's blood count results, the FMF level calculated by FMF-FDM obtained from the disease history questionnaire, and the FMF gene mutation, which has an important place in the diagnosis of the disease. Here, FMF diagnosis will be made by making a decision from the disease inference table given in Table 2.3, prepared with the help of an expert, using the result values obtained to make a decision with FMF-FDM.

3.Application Example

Two examples will be given as FMF-FDM applications designed for FMF diagnosis. The FMF gene mutation was set to be positive in one sample and negative in the other.

3.1. Gene Mutation Positive Application Example

In this example, the evaluation of a situation with a positive FMF gene mutation and whose input values are given in Table 3.1 will be made with FMF-FDM.

Table 3.1. Application example 3.1. Blood count and disease history survey results

CRP (mg/l)	WBC (10^3/ml)	ESR (mm/s)	SAA(mg/dl)	D.H. Survey
6.5	10.5	15.8	13	6

First, CRP, WBC, ESR, SAA and D.H.S. given in Table 3.1. Let's calculate the membership degrees of the fuzzy sets of verbal values of "low", "normal" and "high" parameter values, respectively.

CRP: $\mu_{low}(6.5) = 0$ $\mu_{normal}(6.5) = 0.5$ $\mu_{high}(6.5) = 0.5$

WBC: $\mu_{low}(10.5) = 0$ $\mu_{normal}(10.5) = 0$ $\mu_{high}(10.5) = 1$

ESR: $\mu_{low}(15.8) = 0.42$ $\mu_{normal}(15.8) = 0.58$ $\mu_{high}(15.8) = 0$

SAA: $\mu_{low}(13) = 0$ $\mu_{normal}(13) = 0$ $\mu_{high}(13) = 1$

D.H. Survey: $\mu_{low}(6) = 0$ $\mu_{normal}(6) = 0.67$ $\mu_{high}(6) = 0.33$

Thus, it completed the fuzzing process of the input values. According to this data, out of 243 inference rules, 8 rules given in Table 3.2 are triggered.

Table 3.2. Rule table for application example 3.1.

RULE		CRP	WBC	ESR	SAA	D. H. SURVEY		FMF LEVEL
1	If	Normal	High	Low	High	Normal	If so	Middle
2	If	Normal	High	Normal	High	Normal	If so	Middle
3	If	High	High	Low	High	Normal	If so	Middle
4	If	High	High	Normal	High	Normal	If so	Middle
5	If	Normal	High	Low	High	High	If so	High
6	If	Normal	High	Normal	High	High	If so	High
7	If	High	High	Low	High	High	If so	High
8	If	High	High	Normal	High	High	If so	High

Membership degrees of the entered parameters in the fuzzy set they belong to are given in Table 3.3. Since the membership degree of the membership function of the output of each triggered rule was used with the "AND" connector, the minimum of the inputs was taken and the maximum of the minimums among the triggered rules was taken.

Table 3.3. Rules and membership levels triggered for Application example 3.1.

RULE	CRP	MEMB. DEĞR.	WBC	MEMB. DEGR.	ESR	MEMB. DEGR.	SAA	MEMB. DEGR.	D.H. SURVEY	MEMB. DEGR.	EXIT	MEMB. DEGR. (MIN)
1	Normal	0.5	High	1	Low	0.42	High	1	Normal	0.67	Middle FMF	0.42
2	Normal	0.5	High	1	Normal	0.58	High	1	Normal	0.67	Middle FMF	0.5
3	High	0.5	High	1	Low	0.42	High	1	Normal	0.67	Middle FMF	0.42
4	High	0.5	High	1	Normal	0.58	High	1	Normal	0.67	Middle FMF	0.5
5	Normal	0.5	High	1	Low	0.42	High	1	High	0.33	High FMF	0.33

6	Normal	0.5	High	1	Normal	0.58	High	1	High	0.33	High FMF	0.33
7	High	0.5	High	1	Low	0.42	High	1	High	0.33	High FMF	0.33
8	High	0.5	High	1	Normal	0.58	High	1	High	0.33	High FMF	0.33

Since the center of gravity method is used in defuzzification

$$\text{Gravity Center}= \frac{60\times0.5 + 80\times0.33}{0.5+0.33} = 67{,}9$$

the result is found. According to Table 3.2, which was created with the help of a specialist physician, with the result of 67.9 found by FMF-FDM and the positive values of FMF gene mutation, someone with these data is an FMF patient. Colchicine (2*1) treatment should be started. Routine checks every 3 months is recommended.

3.2. Gene Mutation Negative Application Example

In this example, the evaluation of a situation with a negative FMF gene mutation and whose input values are given in Table 3.4 will be made with FMF-FDM.

Table 3.4. Application example 3.2. Results of a blood count and disease history questionnaire

CRP (mg/l)	WBC (10^3/ml)	ESR (mm/s)	SAA (mg/dl)	D.H. Survey
1.8	4.2	28	7.8	1

First, CRP, WBC, ESR, SAA and D.H.S. given in Table 3.1. Let's calculate the membership degrees of the fuzzy sets of verbal values of "low", "normal" and "high" parameter values, respectively.

CRP:	$\mu_{low}(1.8) = 1$	$\mu_{normal}(1.8) = 0$	$\mu_{high}(1.8) = 0$
WBC:	$\mu_{low}(4.2) = 0.93$	$\mu_{normal}(4.2) = 0.07$	$\mu_{high}(4.2) = 0$
ESR:	$\mu_{low}(28) = 0.2$	$\mu_{normal}(28) = 0.8$	$\mu_{high}(28) = 0$
SAA:	$\mu_{low}(7.8) = 0.73$	$\mu_{normal}(7.8) = 0.27$	$\mu_{high}(7.8) = 0$
D.H. Survey:	$\mu_{low}(1) = 1$	$\mu_{normal}(1) = 0$	$\mu_{high}(1) = 0$

Thus, the blurring process of the input values is completed. According to this data, out of 243 inference rules, 8 rules given in Table 3.5 are triggered.

Table 3.5. Rule table for application example 3.2.

RULE		CRP	WBC	ESR	SAA	D. H. SURVEY		FMF LEVEL
1	If	Low	Low	Normal	Normal	Low	If so	No FMF
2	If	Low	Low	Normal	High	Low	If so	No FMF
3	If	Low	Low	High	Normal	Low	If so	No FMF
4	If	Low	Normal	Normal	Normal	Low	If so	No FMF
5	If	Normal	Normal	Normal	Normal	Low	If so	No FMF
6	If	Normal	Normal	High	High	Low	If so	No FMF
7	If	Normal	Low	High	High	Low	If so	Low
8	If	Normal	Normal	High	High	Low	If so	Low

Membership degrees of the entered parameters in the fuzzy set they belong to are given in Table 3.5. Since the membership degree of the membership function of the output of each triggered rule was used with the "AND" connector, the minimum of the inputs was taken and the maximum of the minimums among the triggered rules was taken.

Table 3.6. Triggered rules and membership degrees for application example 3.2

RULE	CRP	MEMB. DEĞR.	WBC	MEMB. DEGR.	ESR	MEMB. DEGR.	SAA	MEMB. DEGR.	D.H. SURVEY	MEMB. DEGR.	EXIT	MEMB. DEGR. (MIN)	MAX
1	Low	1	Low	0.93	Normal	0.2	Normal	0.73	Low	1	No FMF	0.2	0.73
2	Low	1	Low	0.93	Normal	0.2	High	0.27	Low	1	No FMF	0.2	
3	Low	1	Low	0.93	High	0.8	Normal	0.73	Low	1	No FMF	0.73	
4	Low	1	Normal	0.07	Normal	0.8	Normal	0.73	Low	1	No FMF	0.07	
5	Normal	1	Normal	0.07	Normal	0.8	Normal	0.73	Low	1	No FMF	0.07	
6	Normal	1	Normal	0.07	High	0.8	High	0.27	Low	1	No FMF	0.07	
7	Normal	1	Low	0.93	High	0.8	High	0.27	Low	1	Low FMF	0.27	0.27
8	Normal	1	Normal	0.07	High	0.8	High	0.27	Low	1	Low FMF	0.07	

Since the center of gravity method is used in defuzzification

$$\text{Gravity Center} = \frac{20\times0.73+40\times0.27}{0.73+0.27} = 25.4$$

the result is found. According to the 25.4 result found with FMF-FDM and the negative values of FMF gene mutation in Table 2.3, which was created with the help of a specialist physician, someone with these data does not have FMF. It needs to be re-evaluated during the attack. If there is no attack, routine control is recommended every 6 months.

4.Conclusion

In this study; FMF-FDM, a decision support system that will diagnose FMF and assist physicians in the diagnosis process, has been designed. FMF-FDM helps physicians make a rapid and accurate diagnosis by considering all possible possibilities based on the disease history and the patient's blood count results, FMF gene mutation positive-negative. FMF FDM will reduce dependency on specialist personnel, shorten the busy time of hospitals and doctors, accelerate the treatment process thanks to early diagnosis, and will form the basis for new expert systems to be created in the future for this disease. Similar to FMF-FDM, such systems can be designed for other diseases. In addition to this study, a computer-aided fuzzy expert system can be created. In addition to all these, a hybrid system can be created by processing radiological images.

Author Contributions

All authors contributed equally to this work. They all read and approved the final version of the manuscript.

Conflicts of Interest

The authors declare no conflict of interest.

References

[1] Ben-Chetrit, E, Levy, M. Familial Mediterranean Fever. Lancet, 1998, 351, 659-64.

[2] Dubois, D., Prade, H. Fuzzy sets and systems: Theory and applications, Academic Press, New York. 1980.

[3] Filazi,Ö. Purın-pyrimidin fluctatıons of FMF disease (familial mediterranean fever) and DNA, Published Master's Thesis,Graduate school of natural and Applied sciences, Adıyaman University, Adıyaman, 2010.

[4] Gülender, E. Diagnosis of familial Mediterranean fever disease (FMF) with fuzzy logic, Master Thesis, Tokat Gaziosmanpaşa University, Postgraduate Education Institute, 2023.

[5] Heller, H, Sohar, E, Sherf, L, Familial mediterranean fever, Archives of internal medicine, 1958, 102(1), 50-71.

[6] Janeway, T.C, Mosenthal, H, Unusual paroxysmal syndrome, probably allied to recurrent vomiting, with a study of nitrogen metabolism, Transactions of the association of American Physicians, 1908, 23, 504518.

[7] Klir, J. G., Folger, T. A., Fuzzy sets and information, New Jersey, 1988.

[8] Larsen, P.M. "Industrial applications of fuzzy logic control," International Journal of Man-Machine Studies, vol. 12, no. 1, pp. 3–10, 1980.

[9] Mamdani, E.H., Assilian, S., (1975)," An experiment in linguistic synthesis with a fuzzy logic controller", Int. Journal of Man-Machine Studies, 7(1), 1-13

[10] Mamou, H, Cattan, R, La maladie periodique, Semaıne des hopitaux, 1952, 1062-70.

[11] Marmaralı, A, A strange abdominal pain syndrome, Turkish Medical Society Magazine No:12, 1946.

[12] Şen, Z. Fuzzy Logic and modeling principles, Bilge Culture and Art, İstanbul, 2001.

[13] Siegal, S, Benign paroxysmal peritonitis, Annals of Internal Medicine, 1945, 23, 1-21.

[14] Sohar E., Gafni J. Tel Hashomer criteria for the diagnosis of FMF, First International Conference on FMF. London and Tel Aviv: Freund Publishing House, 1997:207.

[15] Sohar E, Gafni J, Pras M, Heller, H. Familial mediterranean fever A survey of 470 cases and review of literature Am J Med 43 (1967) 227.

[16] Takagi, T. and Sugeno, M. Fuzzy identification of systems and its application to modeling and control. IEEE Transactions on Systems, Man, and Cybernetics, SMC-15, (1985) 116-132.

[17] Thakur, S., Raw, S. N., Mishra, P., Sharma, R. Detection of type of thalassemia disease in patients: A fuzzy logic approach, International Journal of Applied Pharmaceutical Sciences and Research, 1(2), 2016, 88-95.

[18] Torun, S., Design of a hierarchical fuzzy expert system for coronary heart disease risk diagnosis and treatment, Selçuk University, Konya,2007.

[19] Tsukamoto, Y. "An approach to fuzzy reasoning method,", in Advances in Fuzzy Set Theory and Applications, Edited by M. M. Gupta, R. K. Ragade, and R. R. Yager, Amsterdam: North-Holland, 1979.

[20] Yılmaz, A. Design of a fuzzy expert system for iron deficiency anemia diagnosis, Selçuk University, Konya, 2012.

[21] Yücebaş, S. C. Bayesian network based medical diagnostic support system, Başkent University, Ankara, 2006.

[22] Zadeh, L.A. Fuzzy sets, Information and Control, 8 (1965) 338–52.

[23] Zimmermann, H.J. Fuzzy set theory and its applications, Kluwer, 1991.

[24] Güzel E. Z., Demirtaş N. An application of decisionmaking problem based on soft expert sets for diagnosing prostate cancer. Balıkesir Üniversitesi Fen Bilimleri Enstitüsü Dergisi, 24(1), 79-90., Doi: 10.25092/baunfbed.930190, (2022).

[25] Güzel Ergül, Z. and Yüksel, Ş., A new type of soft covering based rough sets applied to multicriteria group decision making for medical diagnosis, Mathematical Sciences and Applications E-Notes, 7 (1): 28-38, (2019).

[26] Demir, İ., N-soft mappings with application in medical diagnosis, Mathematical Methods in the Applied Sciences, 44 (8): 7343-7358, (2021).