Diagnosis of Arthritis Using Adaptive Hierarchical Mamdani Fuzzy Type-1 Expert System

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Abstract

The adroit system is frequently used in artificial intelligence in medicine (AIM). They comprise medical information about a dedicated task and prone to purpose with data from case studies to produce lucid results. Though there are many irregularities, the information with an adroit network is derived with a set of expert rules to produce accurate results. Arthritis is the stiffness of one or more joints and about three fourth of the victims are suffering from it. Late detection of that chronic disease may cause the severity of the sickness at greater risk. So the idea is to contemplate a mechanism for the detection of arthritis using an adaptive hierarchical Mamdani fuzzy expert system (DA-AH-MFES). It is a befitting source to process ambiguity and inaccuracy. Physical and some medical parameters with the expertise of doctors can be mapped using MFES. The ability of MFES completely depends on the rules which are finalized by a discussion with an expert. The expert system has eight input variables at layer-I and four input variables at layer-II. At layer-I input variables are rest pain, morning stiffness, body pain, joint infection, swelling, redness, past injury and age that detects output condition of arthritis to be normal, infection and/or other problem. The further input variables of layer-II are RF, ANA, HLA-B27, ANTI-CCP that determine the output condition of arthritis. The performance of proposed Diagnose arthritis disease using an adaptive hierarchical mamdani fuzzy expert system is evaluated with expert observations of Cavan General Hospital Lisdaran, Cavan, Ireland and Jinnah Hospital Lahore, Pakistan. The accuracy of the expert system (DA-AH-MFES) is 95.6%.

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1. Introduction

Arthritis is the stiffness of one or more than one of your joints. Normally it is considered that if it influences old people but it can attack any age person. It is a chronic disease and a term that includes a group of disorders that affect joints and muscles [1]. Arthritis is a lifelong disorder and approximately three fourth of the sufferers are tormented by it; if it remains undiagnosed it may also cause the severances of the disorder [2, 3]. There are two major infections of arthritis; the first one is osteoarthritis when osteoarthritis infection attacks the person's joints cartilage becomes indentation on the surface, difficult and brittle. The bone below the cartilage get thickens and also broadens out, the amount of lubrication liquid of joints decreases. In a few instances, bony outgrowths may additionally shape at the outer edges of the joint, making

the joint seem tender. Due to osteoarthritis infection sufferer feels severe pain during movement [4].

The second type of arthritis infection is rheumatoid, in this infection membrane of joints swollen. Common symptoms of that infection feel by sufferer are stiffness, body temperature and redness. So to live a happy and healthy life it is very important to diagnose and cure that infection on time. If it remains undiagnosed in sufferer or late-diagnosed it may cause many other problems for sufferer [5]. Different expert systems are used in artificial intelligence in medical field to diagnose and cure different diseases. In this paper fuzzy logic controller is used to design an arthritis disease diagnose system. It is a very good tool that deals with uncertainty and imprecision. It is widely used in artificial intelligence to diagnose different diseases with high accuracy [6, 7, 8].

In this article proposed a fuzzy based intelligent system that will be able to diagnose arthritis at its early stage. The proposed system contains two layers to detect and ensure sufferer disease. Few physical parameters are used at layer-I to know about the type of infection sufferer has, if layer-I confirms that sufferer has arthritis infection then layer-II become an active layer. On layer-II few medical parameters will be used to diagnose the type of arthritis infection and also the stage of that infection. The above-explained process to diagnose arthritis is performed with the recommendation of medical experts in any sufferer.

2. Literature Review

Arthritis is an ailment, Phrase 'arthritis' precisely way tenderness of the joints. The perceived and the existent studies prove that arthritis isn't always a diagnosis in itself. It is a widespread term that mentors us that something is incorrect [9, 10]. The recent researches have used the fuzzy inference system model to diagnosis arthritis based on some physical symptoms and medical tests. The most promising controller known as fuzzy logic that determines membership functions with decides rules about diagnosis results. The designed controller diagnosed arthritis in a single layer by combining different physical and medical parameters. Parameters involved and employed showed a different level of accuracy. The proposed model of that team used physical parameters like body pain and redness and medical parameters rheumatoid Factor (RF) and anti-cyclic citrullinated peptide antibody (ANTI-CCP). It shows accuracy between 8% – 82% [11, 12, 13].

Different causes which are considered baseline for arthritis disease. Worldwide research of his team observed fifty confirmed patients of rheumatoid arthritis having age twenty to sixty to know about common symptoms for future sufferers. They ensured in work that a common symptom that was present in sufferers and not in healthy subjects was the automated nervous system. Due to the presence of that symptoms sufferer does not feel well and does not communicate with others which leads to a short communication problem in the sufferer [14, 15]. Although there are other infections of arthritis that exists but most

Common type of arthritis that is rheumatoid arthritis, prolonging the type Rheumatoid Arthritis, when and how it attacks the person, along with causes based on genetic symptoms, along with the symptoms, the medical remedies are also been discussed in the limelight of the arthritis [16].

Taking into account the vivid types of arthritis, osteoarthritis ailment, wear and tear infection leads to damage of cartilage and slowly cartilage damage fully and the person unable to move and work properly. The type osteoarthritis is considered to be very complex and it is a totally cartilage driven problem so it is very important to diagnose it immediately and cure it on time [17]. To analyze the origin of Rheumatoid Arthritis Smolen utilized dataset from different areas and discussed with arthritics experts. Treat to target (T2T) is used by experts of the Smolen team to cure Rheumatoid Arthritis [18]. The comprehensive discussion leads to the relation between depression and chronic rheumatoid arthritis. They utilized more than a hundred patient dataset including 77% males and 23% females. The result of the study of those patients reveals that more than 40% of the patient including both genders has some degree of depression present in their minds. The suggestions necessitate that it's miles important for treating Rheumatoid Arthritis victims to screen them for melancholy and manipulate it respectively [19]. The most alarming ailments have made the researches to approach the basic plain-film diagnosis and differential diagnosis of the arthritides and analysis of which part of the joint is involved, and works through a logical sequence to reach a final ailment [20].

A different kind of methodology has provided medical researches with a different guideline to diagnose and reduce rheumatoid arthritis. The two targeted types of sufferers have been implicate in paper and recommended different medications as per the severity of an ailment. The study of that paper reveals that although we cannot recommend it to all patients it may help us in more than half cases to reduce the infection of rheumatoid arthritis [21].

Computational Intelligence approaches like Fuzzy system [22,23], Neural Network [24], Swarm Intelligence [25] & Evolutionary Computing [26] like Genetic Algorithm [27, 28], DE, Island GA [29], Island DE [29,30] are strong candidate solution in the field of smart city [31, 32] and smart health [34,35,36,37] etc.

3. Related Work Fuzzy Based System Model

Our proposed Diagnosis of Arthritis Using Adaptive Hierarchical Mamdani Fuzzy Expert System (DA-AH-MFES) is described in this area. Figure 1 determines the evolution of the proposed DA-AH-MFES hierarchical approach. The DA-AH-MFES based expert System includes two layers as appeared in figure 2. In layer-I examine the Arthritis (Negative/Positive) using eight input

variables age, morning-stiffness, body-pain, joint-infection, rest-pain, redness, swelling, past-injury and in layer-2 examine the arthritis (no/acute arthritis/chronic arthritis) using four input variables RF, ANA, HLA-B27, Anti-CCP as performed in figure 3 and figure 4 using MATLAB R2019a tool [33].
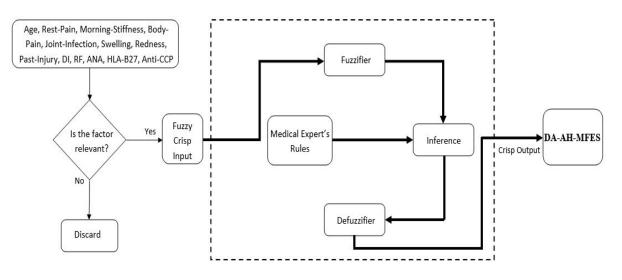

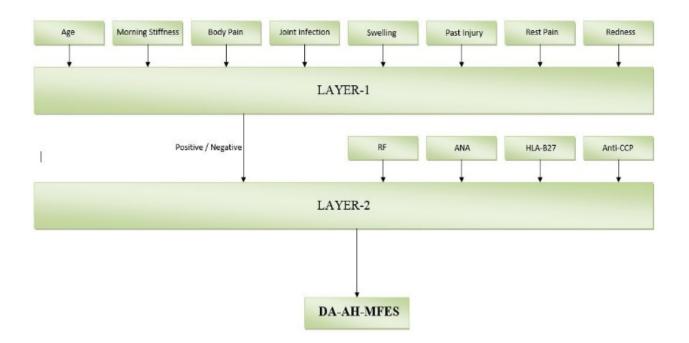**Figure 1.** Proposed DA-AH-MFES based Expert System Methodology

Figure 2. Proposed DA-AH-MFES Expert System

Figure 3. Layer-1 of Proposed DA-AH-MFES Expert System using MATLAB R2019a tool
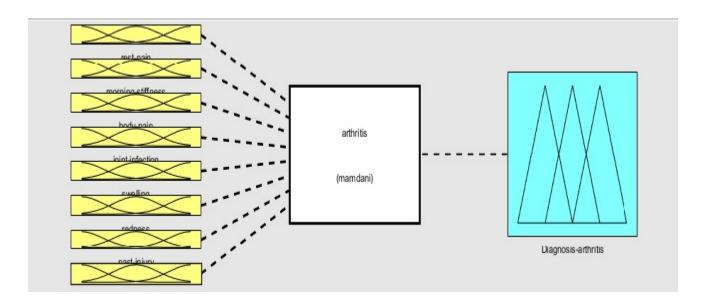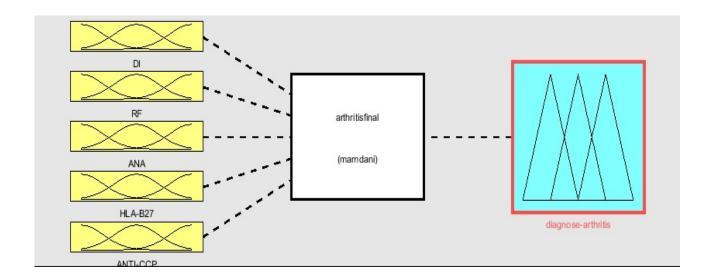

Figure 4. Layer-2 of Proposed DA-AH-MFES Expert System using MATLAB R2019a tool

The values of these parameters are also used to build up a lookup table given in Table-1 to evaluate the type of infection. The proposed automated Diagnosis Arthritis using mamdani inference based expert system can be expressed in mathematically regarding t-norm as

Proposed DA-AH-MFES for Layer-1 can be written mathematically as

$\mu_{\text{DIAGNOSIS-ARTHRITIS,L-1}}$ (da-infection) = t [μ_{AGE} (age) , $\mu_{\text{MORNING-STIFFNESS}}$ (ms) , $\mu_{\text{BODY-PAIN}}$ (bp) , $\mu_{\text{JOINT-INFECTION}}$ (ji), $\mu_{\text{DIAGNOSIS-}}$

$_{\text{ARTHRITIS,L-1}}$ (da-infection) = t [μ_{AGE} (age) , $\mu_{\text{MORNING-STIFFNESS}}$ (ms) , $\mu_{\text{BODY-PAIN}}$ (bp) , $\mu_{\text{JOINT-INFECTION}}$ (ji), $\mu_{\text{DIAGNOSIS-}}$

$_{\text{ARTHRITIS,LA-1}}$ (da-infection) = min [μ_{AGE} (age) , $\mu_{\text{MORNING-STIFFNESS}}$ (ms) , $\mu_{\text{BODY-PAIN}}$ (bp) , $\mu_{\text{JOINT-INFECTION}}$ (ji), μ_{SWELLING} (sw),

$\mu_{\text{PAST-INUJURY}}$ (pi), $\mu_{\text{REST-PAIN}}$ (rp), μ_{REDNESS} (rn)]

& Proposed DA-AH-MFES for Layer-2 can be written mathematically as

$$\mu_{\text{DIAGNOSIS-ARTHRITIS,L-2}} (da) = t\,[\mu_{\text{DI}} (di),\, \mu_{\text{RF}} (rf)\,,\, \mu_{\text{ANA}} (ana)\,,\, \mu_{\text{HLA-B27}} (hla)\,,\, \mu_{\text{ANTI-CCP}} (ac)]$$

$$\mu_{\text{DIAGNOSIS-ARTHRITIS,L-2}} (da) = \min\,[\mu_{\text{DI}} (di),\, \mu_{\text{RF}} (rf)\,,\, \mu_{\text{ANA}} (ana)\,,\, \mu_{\text{HLA-B27}} (hla)\,,\, \mu_{\text{ANTI-CCP}} (ac)]$$

3.1 Input Variables

Proposed system Fuzzy input variables are numerical values that are used to diagnose arthritis. In this research, both layers used a total of twelve different kinds of input variables. Eight variables are used at layer-I and the remaining four variables are used at layers-II. The details of these input and output variables along with their ranges are shown in table 1, table 2 and table 3.

Table 1. Layer-I input variables with medical ranges of proposed DA-AH-MFES expert system

Sr #	Input Parameters	Medical Ranges	Semantic Sign
1	AGE	LT < 18	Child
		B/W 15 - 40	Young
		GT > 37	Old
2	MORNING STIFFNESS	LT < 0.2	No Pain
		B/W 0.1 - 0.5	Minimum
		GT > 0.4	Maximum
3	BODY PAIN	LT < 17	No Pain
		B/W 10 – 43	Minimum
		GT > 35	Maximum
4	JOINT INFECTION	LT < 7	No
		B/W 4 – 45	Minimum
		GT > 42	Maximum
5	SWELLING	LT < 13	No
		B/W 8 – 45	Minimum
		GT > 40	Maximum
6	REDNESS	LT < 13	No
		B/W 8 – 45	Low
		GT > 40	Maximum
7	PAST INJURY	LT < 15	No
		B/W 7 – 42	Minimum
		GT > 35	Maximum
8	REST PAIN	LT < 0.20	No Pain
		B/W 0.1 - 3.5	Minimum
		GT > 3.4	Maximum

Table 2. Layer-II input variables with medical ranges of proposed DA-AH-MFES expert system

Sr #	Input Parameters	Ranges	Semantic Sign
1	Rheumatoid Factor (RF)	LT < 15	No
		B/W 7 – 42	Minimum
		GT > 35	Maximum
2	Antinuclear antibody (ANA)	LT < 0.9	Negative
		GT > 0.5	Positive
3	HLA-B27	LT < 0.9	Negative
		GT > 0.5	Positive
4	ANTI-CCP	LT <15	No
		B/W 7-50	Minimum
		GT > 40	Maximum

3.2 Output Variables

In this research, the multilayered mechanism is proposed to diagnose the Arthritis. If the layer-I output is positive then layer-II is activated. Output variables for both layers are shown in table 3.

Table 3. Layer-I & Layer-II output variables of proposed DA-AH-MFES expert system

Sr #	Layers	Output Variables	Semantic Sign
1	Layer-I	Diagnose infection	Negative
			Positive
2	Layer-II	DA-AH-MFES	No Arthritis
			Acute Arthritis
			Chronic Arthritis

3.3 Membership Functions

Membership functions of the proposed automated DA-AH-MFES Adroit System give the curve value except for truth values and also dispense a mathematical form of fuzzy logic that propose numerical values of both input and output variables. The membership function of this proposed automated DA-AH-MFES adroit system is shown in table 4, table 5 and table 6. These membership functions are established with the help of Cavan General Hospital Lisdaran, Cavan, Ireland and Jinnah Hospital Lahore, Pakistan medical experts.

Table 4. Mathematical & Graphical MF of Layer-1 Mamdani Fuzzy Inference System Input variables

Input	Membership Function	Sample MF Screenshot
Age = A $\mu_{AGE}(a)$	$\mu_{AGE,CHILD}(a) = \begin{cases} 1 & ,if\ a \in [0, \\ \dfrac{18-a}{3} & ,if\ a \in [15, \\ 0 & ,otherwise \end{cases}$ $\mu_{AGE,YOUNG}(a) = \begin{cases} \dfrac{a-15}{3} & ,if\ a \in [15, \\ 1 & ,if\ a \in [18, \\ \dfrac{40-a}{3} & ,if\ a \in [37 \\ 0 & ,otherwise \end{cases}$ $\mu_{AGE,OLD}(a) = \begin{cases} \dfrac{a-37}{3} & ,if\ a \in [37,4 \\ 1 & ,if\ a \in [40,70 \\ 0 & ,otherwise \end{cases}$	
Morning Stiffness = ms $\mu_{MORNINGSTIFFNESS}($	$\mu_{MS,NO\ PAIN}(ms) = \begin{cases} 1 & ,if\ ms\ \epsilon \\ \dfrac{0.2-ms}{0.1} & ,if\ ms \\ 0 & ,otherw \end{cases}$ $\mu_{MS,MIN}(ms) = \begin{cases} \dfrac{ms-0.1}{0.1} & ,if\ ms \in [0 \\ 1 & ,if\ ms \in [0. \\ \dfrac{0.5-ms}{0.1} & ,if\ ms \in [\\ 0 & ,otherwis \end{cases}$ $\mu_{MS,MAX}(ms) = \begin{cases} \dfrac{ms-0.4}{0.1} & ,if\ ms \in [0 \\ 1 & ,if\ ms \in [.5, \\ 0 & ,otherwis \end{cases}$	
Body Pain =bp $\mu_{BODY\ PAIN}(bp)$	$\mu_{BP,NO\ PAIN}(bp) = \begin{cases} 1 & ,if\ bp \in [\\ \dfrac{17-bp}{7} & ,if\ bp \in \\ 0 & ,otherwi \end{cases}$ $\mu_{BP,MIN}(bp) = \begin{cases} \dfrac{bp-10}{7} & ,if\ bp \in [10, \\ 1 & ,if\ bp \in [17, \\ \dfrac{43-bp}{8} & ,if\ bp \in [35 \\ 0 & ,otherwise \end{cases}$ $\mu_{BP,MAX}(bp) = \begin{cases} \dfrac{bp-35}{8} & ,if\ bp \in [35 \\ 1 & ,if\ bp \in [43,4 \\ 0 & ,otherwise \end{cases}$	

Joint Infection =ji $\mu_{Joint\ INFECTION}(ji)$	$\mu_{JI,NO}(ji) = \begin{cases} 1 & ,if\ ji \in [0,4] \\ \dfrac{7-ji}{3} & ,if\ ji \in [4,7] \\ 0 & ,otherwise \end{cases}$ $\mu_{JI,MIN}(ji) = \begin{cases} \dfrac{ji-4}{3} & ,if\ ji \in [4,7] \\ 1 & ,if\ ji \in [7,42] \\ \dfrac{45-ji}{3} & ,if\ ji \in [42,45] \\ 0 & ,otherwise \end{cases}$ $\mu_{JI,MAX}(ji) = \begin{cases} \dfrac{ji-42}{3} & ,if\ ji \in [42,45] \\ 1 & ,if\ ji \in [45,48] \\ 0 & ,otherwise \end{cases}$	
Swelling= Sw $\mu_{SWELLING}(sw)$	$\mu_{SW,NO}(sw) = \begin{cases} 1 & ,if\ sw \in [0,8] \\ \dfrac{13-sw}{5} & ,if\ sw \in [8, \\ 0 & ,otherwise \end{cases}$ $\mu_{SW,MIN}(sw) = \begin{cases} \dfrac{sw-8}{5} & ,if\ sw \in [8, \\ 1 & ,if\ sw \in [13 \\ \dfrac{45-sw}{5} & ,if\ sw \in [4 \\ 0 & ,otherwise \end{cases}$ $\mu_{SW,MAX}(sw) = \begin{cases} \dfrac{sw-40}{5} & ,if\ sw \in [4 \\ 1 & ,if\ sw \in [45, \\ 0 & ,otherwise \end{cases}$	
Redness= rn $\mu_{REDNESS}(rn)$	$\mu_{RN,NO}(rn) = \begin{cases} 1 & ,if\ rn \in [0,8] \\ \dfrac{13-rn}{5} & ,if\ rn \in [8,13 \\ 0 & ,otherwise \end{cases}$ $\mu_{RN,MIN}(rn) = \begin{cases} \dfrac{rn-8}{5} & ,if\ rn \in [8, \\ 1 & ,if\ rn \in [13, \\ \dfrac{45-rn}{5} & ,if\ rn \in [40 \\ 0 & ,otherwise \end{cases}$ $\mu_{RN,MAX}(rn) = \begin{cases} \dfrac{rn-40}{5} & ,if\ rn \in [40, \\ 1 & ,if\ rn \in [45,4 \\ 0 & ,otherwise \end{cases}$	

Input	Membership Function	Sample MF Screenshot
Past Injury= pi $\mu_{PAST\ INJURY}(pi)$	$\mu_{PI,NO}(pi) = \begin{cases} 1 & ,if\ pi \in [0,7] \\ \dfrac{15-pi}{8} & ,if\ pi \in [7,15] \\ 0 & ,otherwise \end{cases}$ $\mu_{PI,MIN}(pi) = \begin{cases} \dfrac{pi-15}{8} & ,if\ pi \in [7,15 \\ 1 & ,if\ pi \in [15,35 \\ \dfrac{42-pi}{7} & ,if\ pi \in [35,4 \\ 0 & ,otherwise \end{cases}$ $\mu_{PI,MAX}(pi) = \begin{cases} \dfrac{pi-42}{7} & ,if\ rn \in [35,4 \\ 1 & ,if\ rn \in [42,48 \\ 0 & ,otherwise \end{cases}$	
Rest Pain= rp $\mu_{REST\ PAIN}(rp)$	$\mu_{RP,NO\ PAIN}(rp) = \begin{cases} 1 & ,if\ pi \in [\\ \dfrac{15-pi}{8} & ,if\ pi \in [\\ 0 & ,otherwis \end{cases}$ $\mu_{RP,MIN}(rp) = \begin{cases} \dfrac{pi-15}{8} & ,if\ pi \in [7,1 \\ 1 & ,if\ pi \in [15,3 \\ \dfrac{42-pi}{7} & ,if\ pi \in [35,4 \\ 0 & ,otherwise \end{cases}$ $\mu_{RP,MAX}(rp) = \begin{cases} \dfrac{pi-42}{7} & ,if\ rn \in [35,4 \\ 1 & ,if\ rn \in [42,48 \\ 0 & ,otherwise \end{cases}$	

Table 5. Mathematical & Graphical MF of Layer-2 Mamdani Fuzzy Inference System Input variables

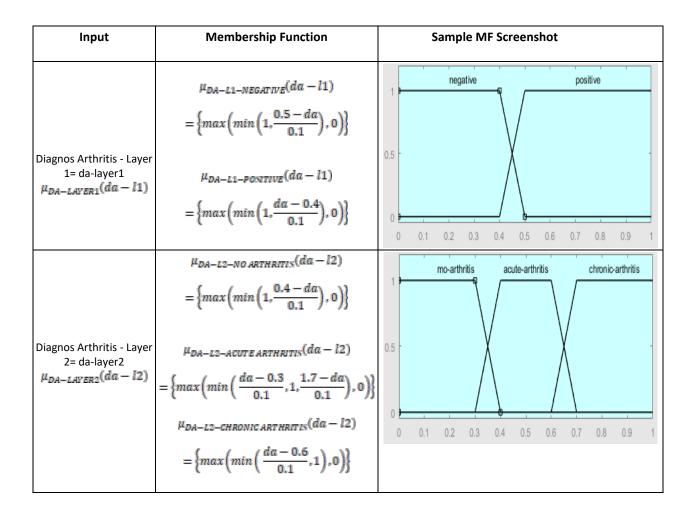| Input	Membership Function	Sample MF Screenshot
Diagnose Arthritis Infection-Layer 1= DI $\mu_{DI}(di)$	$\mu_{DI,NEGATIVE}(di) = \begin{cases} 1 & ,if\ di \in [0,0.4 \\ \dfrac{0.5-di}{a} & ,if\ di \in [0.4,0.5] \\ 0 & ,otherwise \end{cases}$	

Rheumatoid Factor = rf $\mu_{RHEUMATOID\ FACTOR}($	$\mu_{RF,NO}(rf) = \begin{cases} 1 & ,if\ rf \in [0,7] \\ \frac{15-rf}{8} & ,if\ rf \in [7,15] \\ 0 & ,otherwise \end{cases}$ $\mu_{MS,MIN}(ms) = \begin{cases} \frac{rf-7}{8} & ,if\ rf \in [7,15] \\ 1 & ,if\ rf \in [15,35] \\ \frac{42-rf}{7} & ,if\ rf \in [35,42] \\ 0 & ,otherwise \end{cases}$ $\mu_{MS,MAX}(ms) = \begin{cases} \frac{rf-35}{7} & ,if\ rf \in [35,42] \\ 1 & ,if\ rf \in [42,50] \\ 0 & ,otherwise \end{cases}$	
Antinuclear antibody = ANA $\mu_{ANA}(ana)$	$\mu_{ANA,NEGATIVE}(ana)$ $= \begin{cases} 1 & ,if\ ana \in [0,0.5] \\ \frac{0.9-ana}{0.4} & ,if\ ana \in [0.5,0.9] \\ 0 & ,otherwise \end{cases}$ $\mu_{ANA,POSITIVE}(ana)$ $= \begin{cases} \frac{ana-0.5}{0.4} & ,if\ ana \in [0.5,0.9] \\ 1 & ,if\ ana \in [0.9,2] \\ 0 & ,otherwise \end{cases}$	
HLA-B27 =hla $\mu_{HLA-,B27}(hla)$	$\mu_{HLANEGATIVE}(hla)$ $= \begin{cases} 1 & ,if\ hla \in [0,0.5] \\ \frac{0.9-hla}{0.4} & ,if\ hla \in [0.5,0.9] \\ 0 & ,otherwise \end{cases}$ $\mu_{HLAPOSITIVE}(hla)$ $= \begin{cases} \frac{hla-0.5}{0.4} & ,if\ hla \in [0.5,0.9] \\ 1 & ,if\ hla \in [0.9,2] \\ 0 & ,otherwise \end{cases}$	
Anti-cyclic citrullinated peptide = Anti-CCP $\mu_{ANTI-CCP}(ccp)$	$\mu_{CCP,NO}(ccp) = \begin{cases} 1 & ,if\ ccp \in [0,7] \\ \frac{15-ccp}{8} & ,if\ ccp \in [7,15] \\ 0 & ,otherwise \end{cases}$ $\mu_{CCP,MIN}(ccp) = \begin{cases} \frac{ccp-7}{8} & ,if\ ccp \in [7,15] \\ 1 & ,if\ ccp \in [15,35] \\ \frac{42-ccp}{7} & ,if\ ccp \in [35,42] \\ 0 & ,otherwise \end{cases}$ $\mu_{CCP,MAX}(ccp) = \begin{cases} \frac{ccp-35}{7} & ,if\ ccp \in [35,42] \\ 1 & ,if\ ccp \in [45,50] \\ 0 & ,otherwise \end{cases}$	

Table 6. Mathematical & Graphical MF of Layer-1 & Layer-2 Mamdani Fuzzy Inference System Output variables

Input	Membership Function	Sample MF Screenshot
Diagnos Arthritis - Layer 1= da-layer1 $\mu_{DA-LAYER1}(da-l1)$	$\mu_{DA-L1-NEGATIVE}(da-l1)$ $=\left\{max\left(min\left(1,\dfrac{0.5-da}{0.1}\right),0\right)\right\}$ $\mu_{DA-L1-POSITIVE}(da-l1)$ $=\left\{max\left(min\left(1,\dfrac{da-0.4}{0.1}\right),0\right)\right\}$	
Diagnos Arthritis - Layer 2= da-layer2 $\mu_{DA-LAYER2}(da-l2)$	$\mu_{DA-L2-NO\ ARTHRITIS}(da-l2)$ $=\left\{max\left(min\left(1,\dfrac{0.4-da}{0.1}\right),0\right)\right\}$ $\mu_{DA-L2-ACUTE\ ARTHRITIS}(da-l2)$ $=\left\{max\left(min\left(\dfrac{da-0.3}{0.1},1,\dfrac{1.7-da}{0.1}\right),0\right)\right\}$ $\mu_{DA-L2-CHRONIC\ ARTHRITIS}(da-l2)$ $=\left\{max\left(min\left(\dfrac{da-0.6}{0.1},1\right),0\right)\right\}$	

3.4 Rules-Base Lookup Table

For the proposed DA-AH-MFES rules table, which usually relies on the expert system comprises of 6561 input and output rules for layer 1 and 36 input and output rules for layer 2. A few of these input and output rules for layer 1 and layer 2 are presented in table 7 and table 8 respectively. The rule table is generally generated to the assistance of medical experts from the Orthopedic department of Cavan General Hospital Lisdaran, Cavan, Ireland and Jinnah Hospital Lahore, Pakistan.

Table 7. Lookup table of Layer –I for DA-AH-MFES Expert System

Rules	Age	Morning Stiffness	Body Pain	Joint Infection	Swelling	Past Injury	Rest Pain	Redness	Results
1	Child	No	No	No	No	No	No	No	
2	Child	Min	Min	No	Min	Min	No	No	
3	Young	Min	Min	No	No	No	No	Max	
4	Young	Max	No	No	Min	Min	No	No	
5	Old	No	Min	Min	No	No	Min	No	**Negative**
6	Old	Max	No	No	Min	No	Min	No	
7	Child	Min	No	No	Min	Min	Min	Min	

Rules	Age	Morning Stiffness	Body Pain	Joint Infection	Swelling	Past Injury	Rest Pain	Redness	Results
8	Young	No	Max	Max	Max	Min	Min	Max	
9	Old	Min	Max	Max	Max	Min	Min	Max	
10	Old	Max	Min	Max	Min	Max	Max	Min	**Positive**
11	Young	Max	Max	Max	Min	Min	Max	Min	
12	Old	Max	Max	Max	Max	Max	Max	Max	

Table 8. Lookup Table of Layer –II for DA-AH-MFES Expert System

Rules	DI	RF	ANA	HLA-B27	ANTI-CCP	Output
1	Positive	No	Negative	Negative	No	
2	Positive	Minimum	Negative	Negative	No	**No Arthritis**
3	Positive	No	Positive	Negative	No	
4	Positive	No	Negative	Positive	No	
5	Positive	No	Positive	Positive	Minimum	
6	Positive	Minimum	Positve	Negative	Minimum	**Acute Arthritis**
7	Positive	Maximum	Positive	Negative	No	
8	Positive	Minimum	Negative	Positive	Minimum	
9	Positive	Minimum	Negative	Negative	Maximum	
10	Positive	Maximum	Negative	Positive	Minimum	**Chronic Arthritis**
11	Negative	Maximum	Positive	Positive	Minimum	
12	Negative	Maximum	Positive	Positive	Maximum	

Rule-Based

Rules are fundamental for input and output variables for both layers. The accomplishment of an Expert system constructs based on input an output rules. All rules for the proposed DA-AH-MFES appeared in figure 5.

Inference Engine

Inference Engine is the essential constituent of any decision based self-ruling framework. In this exposition of DA-AH-MFES, the Inference model is used in Layer I and Layer II.
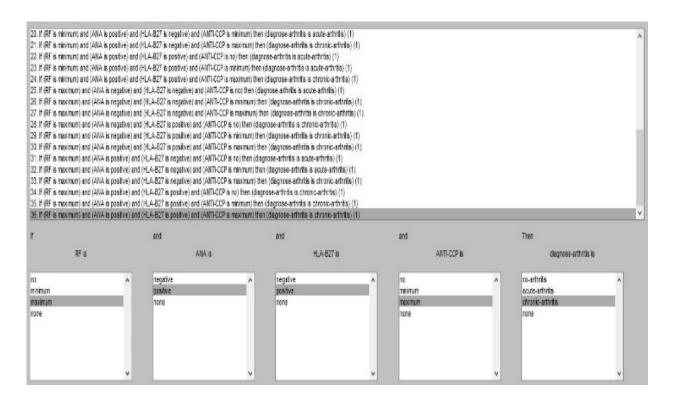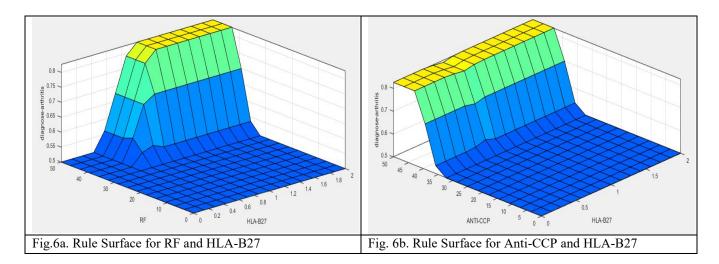
Figure 5. Rules-based system for DA-AH-MFES Adroit System

De-Fuzzifier

De-Fuzzifier is one of the fundamental sections of any decision based self-governing framework. There are different sorts of defuzzifier. In this examination centroid type of De-fuzzifier is used. Figure 6 of all sections 6a-6d, demonstrates the De-fuzzifier graphical representation of both layers administers in DA-AH-MFES.
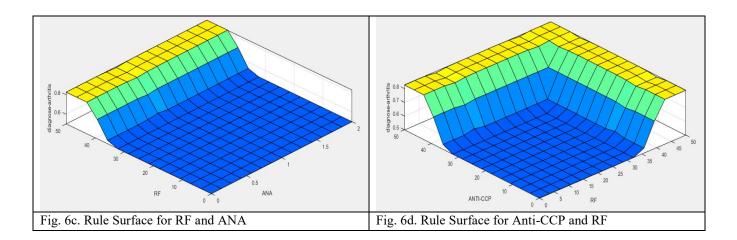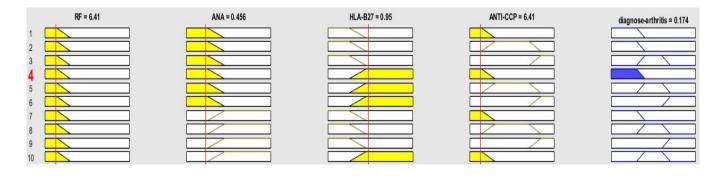

Fig.6a. Rule Surface for RF and HLA-B27	Fig. 6b. Rule Surface for Anti-CCP and HLA-B27

Fig. 6c. Rule Surface for RF and ANA	Fig. 6d. Rule Surface for Anti-CCP and RF

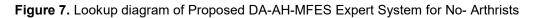**Figure 6.** De-Fuzzifier graphical illustrations of Proposed DA-AH-MFES Expert System

In Figure.6a blue color reperent the no arthritis , green color represent the acute arthritis and yellow color represent the chronic arthritis. The Arthritis (regarding Probability) based on Rheumatoid Factor and HLA-B27. Different colors in the Surface region present the stages of Arthritis. It is also observed that if Rheumatoid Factor is no (with the range between 0-15) and HLA-B27 less than 0.9 then the probability of arthritis is 0 that it may be any other types of arthritis. It is also observed that if the costs of Rheumatoid Factor are more the 35 its mean maximum and amounts of HLA-B27 are less the 0.9, the value of Arthritis is 80% that means it is no & chronic arthritis.
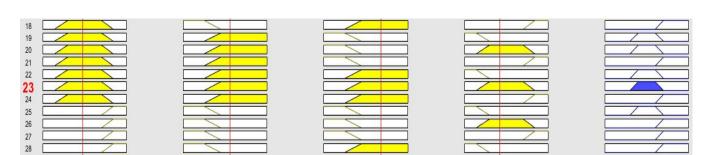
Correspondingly, remaining figures 6b-6d present workmanship results by winning distinctive info parameter values. The surface district speaks to likelihood values by two information factors from given twelve input variables. The arthritis results are the blend of in any event three information factors.

4. Simulation and Results

MATLAB R2019a [33] tool is used for representing, simulated, algorithm development, prototyping, and many other fields. This tool is efficient for software designing, data analysis, outset, and calculations. For the simulation of results, twelve inputs on both layers one output of diagnosing arthritis are used which are shown in figures 7, 8 and 9.
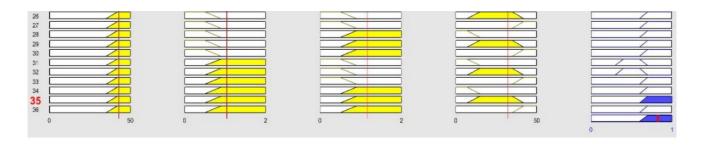

Figure 7. Lookup diagram of Proposed DA-AH-MFES Expert System for No- Arthrists

Figure 8. Lookup diagram of Proposed DA-AH-MFES Expert System for Acute Arthritis

Figure 9. Lookup diagram of Proposed DA-AH-MFES Expert System for Chronic Arthritis

Figure 7 shows, If $\mu_{RHEUMATOID\text{-}FACTOR}$ (rf) is considered no, μ_{ANA} (ana) is negative, $\mu_{HLA\text{-}B27}$ (hla) is positive, $\mu_{ANTI\text{-}CCP}$ (ccp) is no, then Outcome for $\mu_{DA\text{-}LAYER2}$ (da-l2) is No arthritis.

Figure 8 shows, If $\mu_{RHEUMATOID\text{-}FACTOR}$ (rf) is considered minimum, μ_{ANA} (ana) is positive, $\mu_{HLA\text{-}B27}$ (hla) is positive, $\mu_{ANTI\text{-}CCP}$ (ccp) is minimum, then Outcome for $\mu_{DA\text{-}LAYER2}$ (da-l2) is acute arthritis.

Figure 9 shows, If $\mu_{RHEUMATOID\text{-}FACTOR}$ (rf) is considered maximum, μ_{ANA} (ana) is positive, $\mu_{HLA\text{-}B27}$ (hla) is positive, $\mu_{ANTI\text{-}CCP}$ (ccp) is maximum, then Outcome for $\mu_{DA\text{-}LAYER2}$ (da-l2) is chronic arthritis.
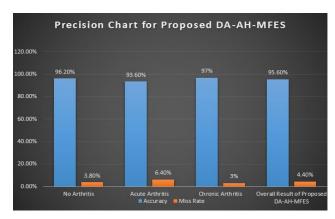

Figure 10. Precision Chart of Proposed DA-AH-MFES Expert System

The viability of the proposed method has sporadically kept an eye on many records. The Proposed DA-AH-MFES expert system gives definite outcomes for all stages, and just at acute arthritis, it might achieve some slight errors. Figure 10 speaks to the precision rate of DA-AH-MFES for the detection of arthritis. The proposed framework demonstrates the exactness rate for no arthritis is 96.20 percent, for acute arthritis is 93.60 percent and for chronic arthritis is 97 percent. The overall precision of the proposed DA-AH-MFES is 95.60 percent and the miss rate of the proposed DA-AH-MFES turns out to be 4.40 percent.

5. Conclusion

The basic point of convergence of our examination is to devise an expert system to examine arthritis by reports retrieved from the Cavan General Hospital Lisdaran, Cavan, Ireland and Jinnah Hospital Lahore, Pakistan. This expert system is principal and simpler to use for both Medical specialists and non-specialists. This research engages orthopedic experts, surgeons and lab technicians for the judgment of the propose DA-AH-MFES expert system performance. Research obtained through the fuzzy logic model is critically analyzed in the supervision of orthopedic experts, surgeons and lab technicians. They conclude that this fuzzy logic model is to provide reliable results in the field of arthritis disease. The particular goal of this study is to analyze the various dimensions of arthritis. The overall accuracy of this proposed DA-AH-MFES is 95.6%. In the future, the productivity of the presented framework can be enhanced utilizing different methods including Computational Intelligence as Deep Learning, Neuro-fuzzy, and Neural networks.

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