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Early Detection of Arthritis using Hierarchical Fuzzy Expert System

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***Abstract:** Purpose: This research aims to discover diagnostic tools using fuzzy logic and artificial intelligence for early detection of Arthritis that can be applied in practice. The complexity of medical practice makes traditional quantitative approaches of analysis inadequate. In medicine, the lack of information (patient information, medical history, physical examination and laboratory results), imprecision and contradictory nature are common facts. This makes diagnosis and treatment difficult for the medical practitioner. These procedures are rigorous, the linguistic approach and human reasoning nature of fuzzy logic makes it easier for medical experts. In addition to this, there is a huge time lag between a patient experiencing the symptoms and actually seeking a doctor's help and this can worsen the situation and can lead to long term malfunctioning. Fuzzy logic and Graphical user Interface focus on targeting and solving these issues. The core objective of the research is designing a system that is cheap and easily accessible by the masses. Design and Methodology: Since the research aims at finding feasible diagnostic tool for assisting physicians and orthopaedics, secondary data from books, articles and engineering research journals was used. All the basics of fuzzy logic and the tool MATLAB were deliberated thoroughly. The chapter and verse for the disease Arthritis was analysed carefully so that the input and output parameters for the fuzzy inference system can be chosen precisely. Membership functions were defined for the chosen parameters. A rule base was designed for implementation. The parameters were combined in a hierarchical workspace so as to reduce the complexity of the system and design a compact model. The fuzzy inference system was then linked to Graphical User Interface for a novice friendly operation. The results were calculated and compiled. The results were then compared with those indicated by an orthopaedic to determine the accuracy of the system. Findings: Applying Fuzzy logic and Artificial Intelligence in Medicine can prove of great potential as it is robust and has the ability to deal with imprecise, distorted and erroneous data. Fuzzy expert system helps in making decisions very accurately which in turn helps medical experts in making decisions timely to avoid long term and permanent damage or complications from Arthritis or any other disease for that matter. Overall, the proposed Artificial Intelligence System produced favorable response based on the expected outcome and experimentations. The entire research was carried out under the guidance and supervision of a renowned orthopedic surgeon, who found the system to be useful as it was able to produce quintessential results.*
***Practical Implications:** The proposed system can assist the diagnosis of Arthritis at an early stage and can even be modified to detect other diseases as well accordingly. It can be further enhanced by combining with image detection and segmentation to analyse the affected bones and joints. The system can also be used to characterize the subtypes and coexisting causes of Arthritis. Furthermore, Neuro-Fuzzy based portable thermo-graphic system can be created that combine the potential of both thermal imaging and fuzzy logic. Research Limitations/Implications: Sample size is a little under-powered because of lack of patient data but can be increased by seeking data from other orthopaedic practitioners. Lack of available data was an obstacle in finding a trend and a meaningful relationship between the possible causes and the outcomes of the disease.*
***Keywords:** Arthritis, Rheumatoid Arthritis, Osteoarthritis, Fuzzy Inference System, Erythrocyte Segmentation Rate (ESR), Antinuclear Antibody, Anti ccp, Rheumatoid Factor, Symmetry of joint infection, Artificial intelligence, Graphical User Interface*

I. INTRODUCTION

Arthritis means joint inflammation. The term "Arthritis" is used to describe around 200 conditions that affect joints, the tissues that surround the joint, and other connective tissues. It is a rheumatic condition [1]. The most common form of arthritis is Osteoarthritis. Other common rheumatic conditions related to arthritis include Gout, Fibromyalgia, and Rheumatoid arthritis (RA) [1].
Rheumatic conditions tend to involve pain, aching, stiffness, and swelling in and around one or more joints. The symptoms can develop gradually or suddenly. Certain rheumatic conditions can also affect the immune system and various internal organs of the body [1]. Some forms of arthritis, such as rheumatoid arthritis and lupus (SLE), can affect multiple organs and cause widespread symptoms [4].

Arthritis is more common among adults aged 65 years or older, but it can affect people of all ages, including children [1].
There is no single cause of any types of arthritis. The cause or causes may vary according to the type or form of arthritis [10].
Possible causes may include

A. Injury, leading to degenerative arthritis
B. Abnormal metabolism, leading to gout and pseudogout
C. Inheritance, such as in osteoarthritis
D. Infections, such as in the arthritis of Lyme disease
E. Immune system dysfunction, such as in RA and SLE

Most types of arthritis have no obvious cause and appear to be unpredictable in their emergence [10].
Key warning signs include

1) *Pain:* Pain from arthritis can be constant, or it may come and go. It may affect only one part, or be felt in many parts of the body.
2) *Swelling:* In some types of arthritis the skin over the affected joint becomes red and swollen and feels warm to the touch.
3) *Stiffness:* Stiffness is a typical symptom. With some types, this is most likely to occur upon waking up in the morning, after sitting at a desk, or after sitting in a car for a long time. With other types, stiffness may occur after exercise, or it may be persistent.
4) *Difficulty in Moving a Joint:* IF moving a joint or getting up from a chair is hard or painful, this could indicate arthritis or another joint problem.
5) *Creaking or Grinding Sounds:* Crepitus is the medical term for the grinding sound often heard when attempting to move the affected joint. Sometimes moving the joint through the full normal range of motion may not even be possible.
6) *Joint Deformity:* The arthritic knee joint can develop a deformity in which the joint itself becomes angled.
7) *Osteophytes:* Joints also may appear swollen, caused by new bony growths called osteophytes (bone spurs) or sometimes, by extra fluid in the joint.

Arthritis is an inflammatory progressive disease which in the absence of appropriate treatment can lead to joint destruction and disability. Identification of Arthritis at initial presentation and treatment at earlier stage can affect disease course, prevent the development of joint erosions or retard progression of erosive disease. Early diagnosis and treatment may affect disease outcomes even to a remission state. Hence early diagnosis of Arthritis is really important.
Currently, Arthritis treatment is limited mostly to over-the-counter pain medications or surgery to change the alignment of the bone, or even replace afflicted joints. Using Fuzzy Logic and Imaging for early detection could lead to preventative methods that could help patients avoid losing joint function in the first place.
Arthritis can be particularly damaging in its initial stages. “Studies have shown that the greatest damage from arthritis occurs early in the disease rather than later”. Early diagnosis and early treatment will prevent a lot of deformities, especially in chronic cases.
Another problem is the time a patient takes between experiencing symptoms and seeing a doctor. This is an international problem. Hence, it is vital to catch the disease early in order to reduce the chances of causing damage to joints.
There are several factors to analyse and to diagnose the arthritis of a patient, and this makes the physician’s job hard as the symptoms can be complicated.
Evaluation of data taken from patient and decisions of experts or orthopaedics are the most important factors in diagnosis without a second thought or doubt but, this is not easy considering the number of factors she/he has to evaluate. To help the experts and remove any possible errors that can be made due to fatigued or in-experienced experts and minimize any errors in the evaluation of the symptoms , classification systems are designed that examine the medical data more precisely and accurately that so in shorter time.
The use of Expert systems and different artificial intelligence techniques for classification systems in medical diagnosis of several diseases is increasing day by day. In a similar way, classification systems have been used for arthritis diagnosis. Alternative knowledge acquisition approaches based on fuzzy logic have recently attracted considerable amount of attention and many physicians and doctors are being lured by these techniques.
The advantage of these methods over other approaches is that they can produce good and more accurate results in situations where data is imprecise, noisy and inconsistent.

They do not require any additional mechanisms or techniques for dealing with imperfect data because they have an inherent ability to deal with uncertainty. The fuzzy expert systems have become so popular that it has aroused a need for automation of not only the process of drawing out the fuzzy rules but also the process of producing the parameters of the related fuzzy sets.

This work aims at applying fuzzy logic to mechanize knowledge acquisition for early diagnosis of Arthritis. These techniques are capable of handling complex and imprecise data. These have proved to be the most suitable evaluation criteria for diagnosis as these provide quintessential accuracy.

II. METHODOLOGY

Fuzzy logic controller is a potential tool for dealing with uncertainty and imprecision. It is successful application of Zadeh's fuzzy set theory [5]. Thus, knowledge of a doctor can be modelled using a fuzzy logic controller [6]. The performance of the system is directly proportional to the knowledge base which comprises of data base and a rule base. Although, it is observed that the rule base effects the performance more and it can be made better and more efficient by optimizing the membership functions stored in the data base. This is a very rigorous and fine tuning process [7].

The process of knowledge extraction is a very complex and labour intensive task in the construction of an expert system and requires precise knowledge about Fuzzy logic and Artificial Intelligence. Lack of knowledge and expertise can lead to error making it Impossible to design and develop such systems. One has to face many difficulties and encounter various obstacles for extracting and attaining knowledge and data from experts as they might have difficulty in expressing or explaining their decision making process.

III.DESIGNING OF FUZZY INFERENCE SYSTEM:

Development of a diagnostic tool for Arthritis or any other disease for that matter requires data. The data should be capable of demonstrating the entire disease along with its severity. The data generally consists of signs and symptoms experienced by the patient, medical history, medical and laboratory reports etc. It is observed that physical symptoms have more weightage in diagnosing the disease than laboratory tests like Blood test, ESR check-ups, Anti-ccp tests, Rheumatoid Factor tests etc. All these are equally important in determining the severity and type of Arthritis. These show different and fluctuating values depending upon the type of Arthritis.

Data and reports were collected from Ganga Orthocare, Jalandhar. 50 patients who were or had undergone treatment from that hospital were examined and analysed.

After studying the data from patients and consulting the doctor, 12 parameters /symptoms were chosen as the inputs for diagnosis of Arthritis. Fig. 1 shows the flowchart for designing the fuzzy inference system. These symptoms proved to be the most relevant in diagnosis of Arthritis. These were entered as the inputs for the fuzzy inference system and the severity of the disease was predicted as the output.

A. Physical Symptoms

1) Body Pain
2) Rest Pain
3) Redness
4) Swelling
5) Stiffness
6) Symmetry of Joint Infection

B. Laboratory Tests

1) Rheumatoid Factor(RF)
2) Erythrocyte Sedimentation Rate(ESR)
3) Uric Acid
4) Anti CCP
5) C Reactive Protein
6) Antinuclear antibody

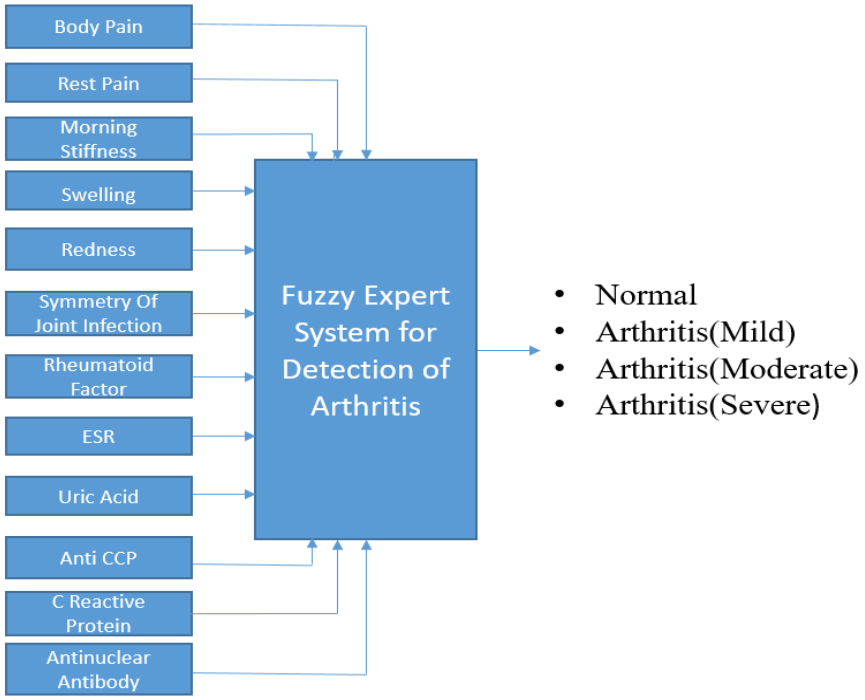


Fig. 1 Flowchart for designing fuzzy inference system

IV. ALGORITHM FOR FUZZY INFERENCE SYSTEM FOR DIAGNOSIS OF SEVERITY OF ARTHRITIS

Using the 12 symptoms of Arthritis, 12 input variables and one output variable "Condition" was created using the Fuzzy Logic toolbox of MATLAB [8]. Fig. 2 shows the rule viewer window. The twelve symptoms used in designing the fuzzy inference system are considered to be most important and crucial in predicting the severity and type of Arthritis. The twelve symptoms (parameters) are divide into four groups of three and membership functions are defined for all depending upon the frequency and percentage value of the symptoms.27 simple if-then rules were defined for each of the groups by combing 3 inputs by AND function. Table 1 shows the parameters, their membership functions and their normal ranges.

Based on these rules the roadmap of the whole fuzzy inference system was designed. Rule viewer displays which rules are active and how the individual functions are influencing the results and outcomes. The four plots on the top represent the antecedent and consequent of the first rule. Each rule is defined by a row of plots, and each column represents a variable. The rule numbers are displayed on the left of each row.

Fig. 2 Rule viewer for fuzzy inference system

There are 109 plots nested in a single figure window. The three columns of the plots (the blue plots) depict the membership functions or the if-part of each rule. The fourth column (the blue plot) depicts the consequent or the then-part of each rule. The plots which are blank in the if-part of any of the defined rule correspond to characterization of none of the variable in the rule. The last plot in the fourth column represents the weighted decision for the proposed inference system. This depends on the input variable functions. The defuzzyfied output is displayed as a bold vertical line on this plot.

Fig. 3 shows the flowchart for the steps taking place in the design of the fuzzy inference system.

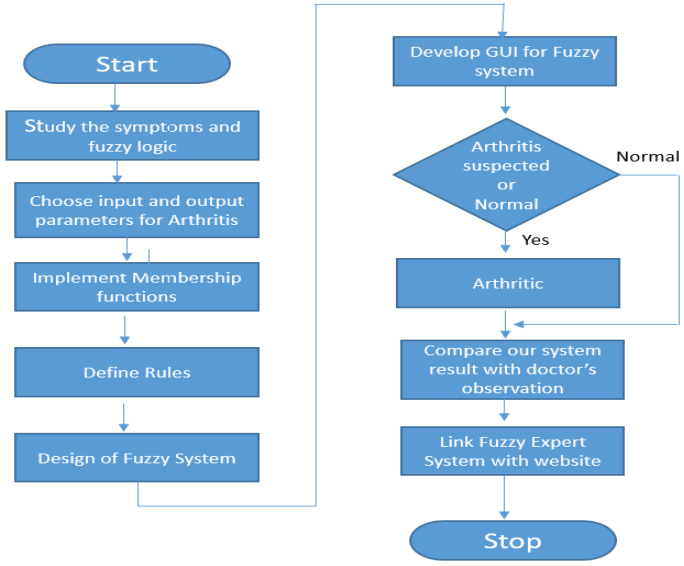
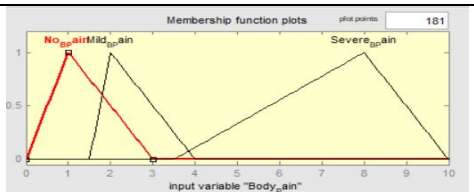
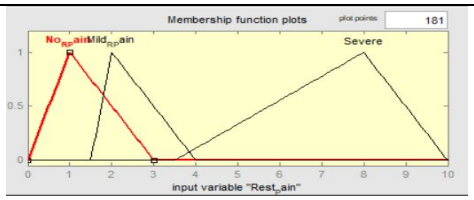
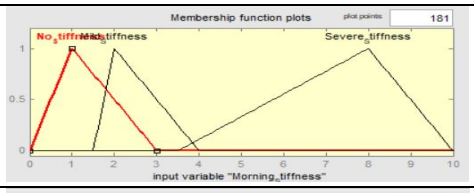
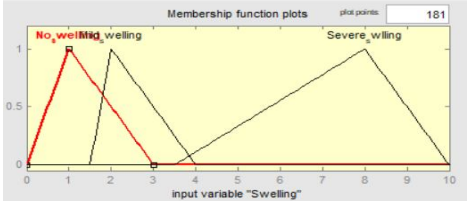
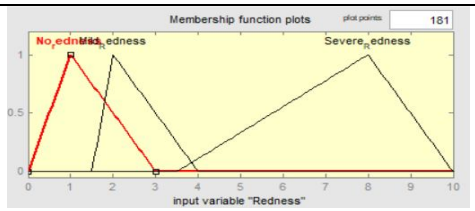
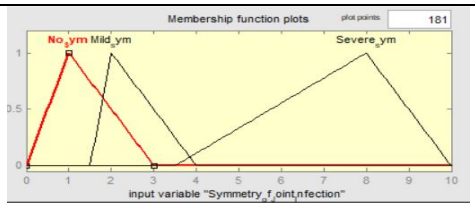
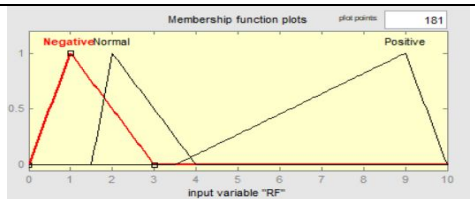
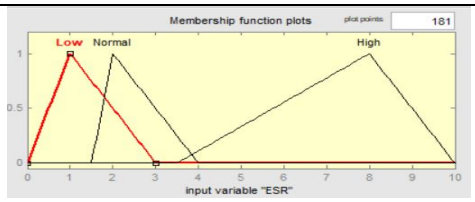
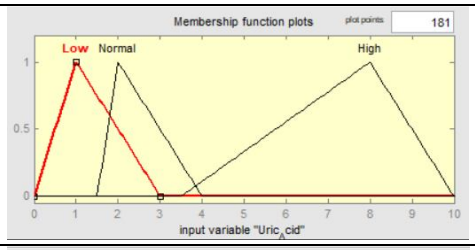
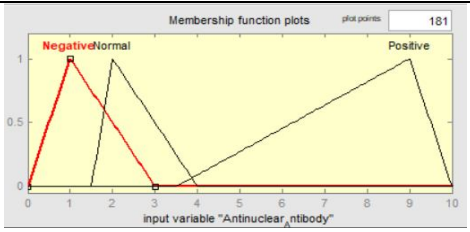
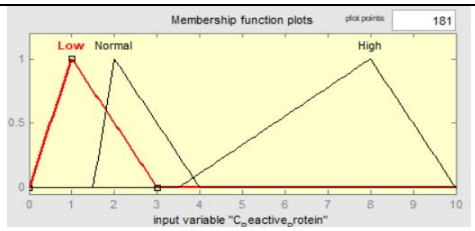
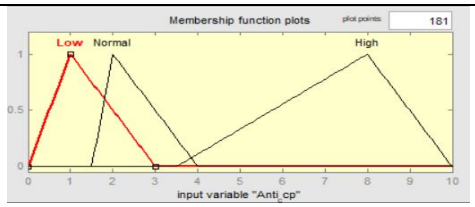


Fig. 3 Flowchart for designing fuzzy inference system

TABLE I
Parameters and their membership functions

Sr. No.	Input Parameters and Membership Functions		
	Input Parameters	Membership Functions	Normal Ranges
1	Body Pain		-
2	Rest Pain		-
3	Morning Stiffness		-
4	Swelling		-

5	Redness		-
6	Symmetry of Joint Infection		-
7	Rheumatoid Factor		10 IU/mL to 20 IU/mL
8	Erythrocyte Sedimentation Rate		0-20 mm/hr/ to 0-30mm/hr
9	Uric Acid		2-7mg/dL
10	Antinuclear Antibody		1:40 to 1:60 titers
11	C Reactive Protein		0-10mg/L
12	Anti ccp		(<20 u/ml)

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V. DESIGNING A GRAPHICAL USER INTERFACE

A Graphical user interface was designed to develop a system that is cheap and easily accessible by the masses. Fig. 4 depicts the Graphical user interface that was designed. The result evaluation and the outcome are shown by Fig. 5 and Fig. 6 respectively.

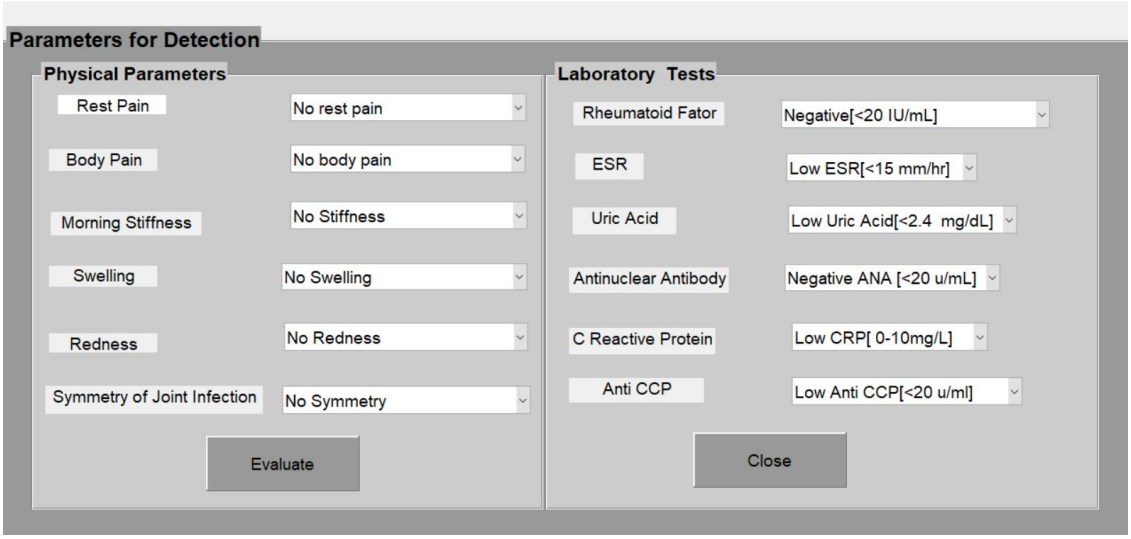

Fig. 4 Arthritis Detection GUI with Input Parameters

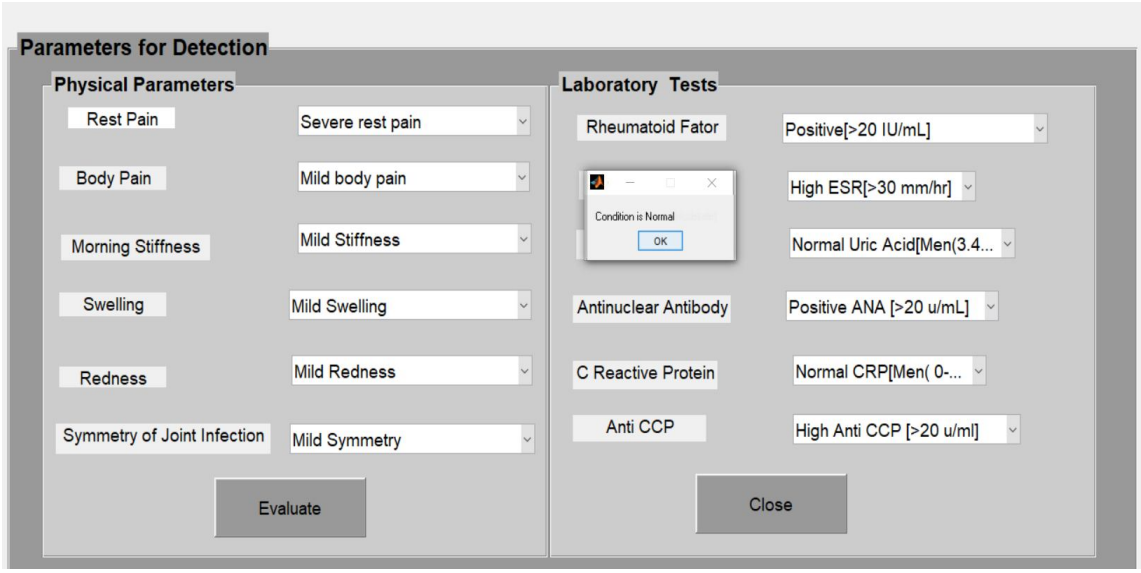

Fig. 5 Result Evaluation using GUI

Condition is Normal [Final Result]	1.14058
Condition is Normal(Parameters used are RF ESR Uric Acid Antinuclear Antibody Creactive Protein AntiCCP)	1.14058
Condition is Normal(Parameters used are Rest Pain Body Pain Morning Stiffness Swelling Redness Symmetry of joint infection)	1.14058
Condition is Normal(Parameters used are Antinuclear Antibody Creactive Protein AntiCCP)	1.14058
Condition is Normal(Parameters used are Rheumatoid Factor ESR Uric Acid)	1.14058
(Condition is Normal (Parameters used are Rest Pain Body Pain Morning Stiffness)	1.14058

Fig. 6 Arthritis Detection using physical and laboratory parameters

VI. TESTING OF ARTHRITIS FUZZY INFERENCE SYSTEM

The proposed system represents recognition of normal and Arthritic condition on the basis of parameters (Rheumatoid factor (RF), Erythrocyte sedimentation rate (ESR), Uric Acid, Anti-CCP, C-Reactive Protein, Antinuclear Antibody (ANA), Rest pain (RP), Morning Stiffness (MS), Symmetry of joint infection (SJI), Redness (RN), Body pain (BP), Swelling (SW)). In this proposed fuzzy inference system there are 108 rules (12 parameters divided into 4 groups of 3 parameters with 27 rules each). 50 patients were examined and the results were compared with those indicated by an orthopedic surgeon. The proposed system proved to provide quintessential accuracy on comparison.

VII. CONCLUSION

Although there is no cure for arthritis, even then appropriate management can help people with arthritis live healthy and independent lives. Physicians believe that damage to bones begins within the first two years that a person has the disease. Early diagnosis can decrease symptoms and long-term complications.Fuzzy expert system helps in making decisions very precisely which in turn helps medical experts in making decisions timely to avoid long term and permanent damage to bones and joints. Fuzzy system allows to lower complexity by allowing the use of imperfect information in a sensible way. To remove the uncertainty of fuzzy logic, graphical user interface (GUI) is used. Fuzzy inference system is linked with graphical user interface. This model can diagnose Arthritis at an early stage. Therefore correct medical treatment can be followed at right stage. This helps the physicians in reaching a more logical conclusion for predicting Arthritis. In our fuzzy inference system 27 rules are defined for 3 parameters combined together. There are 12 parameters in total. Therefore the total number of rules for four parameter combinations are 4*27=108. The results are compared with the observations and diagnosis of orthopedics. The Results show quintessential accuracy which makes our system very exact and precise.

VIII. ACKNOWLEDGMENT

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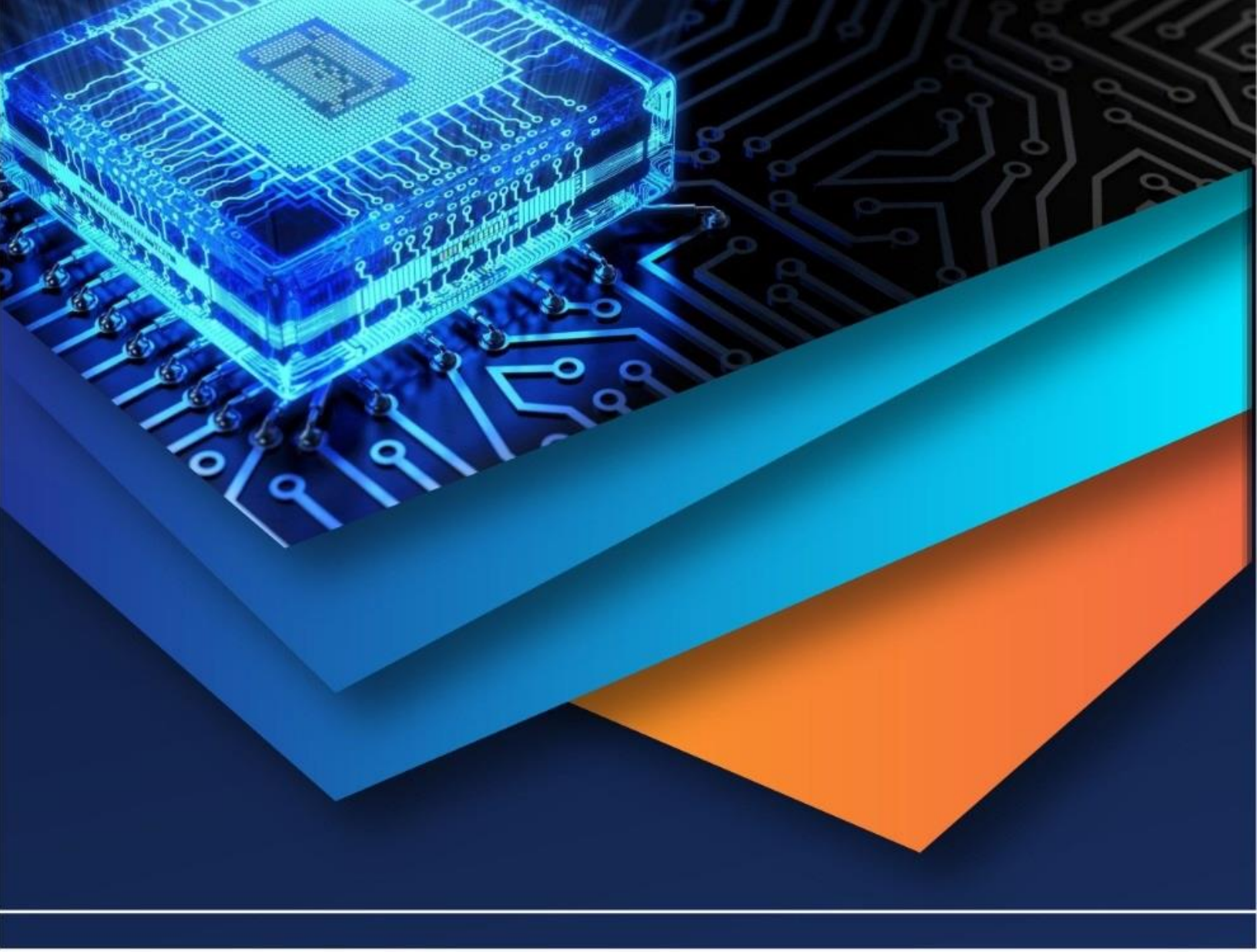

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