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Clinical Decision Support System for Knee Injuries

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***Abstract*—** Health related issues are most common among sports persons. The persons indulging in athletic activities have to face or suffer from various injuries and diseases. Hence sports medicine is a field which is specifically meant for providing medical aid to suffering sport persons. It is such a vast field that lot of amendments can be done in this field. This study provides an overview to the previously done work by various experts. It is seeing that most of the expert systems were created by using some basic technologies which are not in use today. And lot of crucial injuries and diseases were not considered by them such as injuries of knee.

The objective behind this work is to design and implement such a multi agent system which can be able to detect the knee injuries. The work is implemented by using the trending and advance technology of current generation i.e. fuzzy logics or system which is based on some rules of real world application. MATLAB is used as simulation platform to evaluate the proficiency of the present work. The result section shows that how efficiently the system detects the disease and generates medical advice to the patient.

Keywords-Fuzzy logic, Clinical decision making,knee injury treatment.

I. INTRODUCTION

Health and socio-economy is disheveled to each other that it is impossible to achieve one without the other [1]. India has entered into high growth rate but it is a fact that social sector did not have an impact to attain such a growth stratum. The term social development covers the educational development and Healthcare amenities [2].

The healthcare services provided in India are not ample for the agony person. After a survey, it is concluded that India suffers from dearth of health services [3]. The spotlight of this research work is to highlight the health care services provided to the sports persons in India [4]. As the survey conducted by World Health Organization (WHO) in 2000, India was ranked 112 out of 190 countries. Various campaigns have been started in India like E-health programs, New Health policies in 2015 to enhance the medical services provided to the public [5].

Nowadays sports athletes undergo many mental and physical obstacles from their competitive environment.Sports medicine play a crucial role for sports personnel throughout his sports career [6]. Because a person who is related to the sports, can suffers from various injuries throughout his practice session. Sport injuries need a professional treatment because such injuries can lead to great damage to body [7]. Sport Medicine is also known as Sports and Exercise medicine. It is a field that deals with the injuries that happens to the sports persons due to various athletic activities and provides a proper treatment to the sports person by the experts or professionals [8]. The dealing with the injuries can be in the form of medicines, Physiotherapy, exercises by having a stepwise insight to the injury like prevention, diagnosis and treatment [9].

Injury refers to the physical damage to the body or any of body parts [10]. It can happen because of falls, hits, imbalance of body or other causes [11]. The injuries can be specified in two type i.e. External injury such as wounds and internal injuries that cause damage to muscles. The sports person can suffers from various injuries such as “Impact” which causes due to tackle [12], hit, dribble fender-bender with someone and other type of injury is that cause due to changes in environment like dehydration, hypothermia etc [13].

Figure 1 Ligament Knee Injury[33]

The figure above shows the image of ligament knee injury. It joins the back of the thighbone with front of the shinbone.Other sports injuries are listed as follows [14]:

a) Concussions: types of disease which causes due to head injury. Example: Seizure.

b) Muscle Cramps: cause of muscle cramps is sudden tihghtness, pain in muscles.

c) ACL sprains: Anterior Cruciate Ligament spains involves in Knee stabilization.

d) ACL tears: ACLS which is concerned with knee comfort such as movement or tears that lead to pain in the knee.

e) Shin Splint: is a injury which happens to the lower muscles of leg due to any kind of pull stretching of the shin bone.

Sports Medicine provides treatment to the injured sports person. Traditionally, personal physician was hired by the sportsmen for their own [13]. But now an exceptional medical service is provided to the sports persons in the form of sports medicine [16].

From last few years many countries have established national associations of sports [17]. Indian government has also been actively promoting sports and related activities such as better infrastructure, sports medicines, and well conditioned sport's accessories etc. Sports Medicine is one of emerging field and attracts researchers to work upon [18].

II. RELATED WORK

The Purpose of this section is to present an overview of the scientific and clinical discipline known as Sports medicine. In a diverse world like ours it is not surprising to see that there is no single definition of sports medicine that is accepted by all interested in the field. Different researchers throughout the world have their own conceptual and practical definition of sports medicine. The following heterogeneity defines that how sports medicine is growing nowadays.

Zelic I, Kononenko I et al,[3]developed the expert system shell which has many machine learning algorithms incorporated in it to extract the knowledge from the database about the injuries in the sports. The objective of this paper is to create such a system which can detect the injury in muscle located backside of the thighs. They used this system on the stand alone computers. Patients have to come to the hospitals for the diagnosis of its injuries. Further these system where used by the expert doctors for their convenience

Jun Huang, [2]focused on the inter-related communication between the individuals in hospitalswho involves in the treatment like testing laboratory, nurses etc.The proposed system was developed to detect the cancer in patients. The process of inter related communication can be run smoothly with the use of software system. The research described an agent based software system that can ensure the smooth communication during medical treatment.

Stan McCellan et al, [5] gave the demerits of how the web based distributed-object application can't be the state of art software development model. It is generally recognized that current Web technologies are insufficient for supporting complex, enterprise-class applications such as distributed, network-based healthcare applications. The poor structural support for maintenance, re-use create nightmarish requirement for web page updates, web site redesign and ad-hoc user-interfaces. He proposed next generation technology like XML, DOM, HTTP-NG and WIDL for making sports medicines eXchanger website to cater the need of user with providing information related to intricate sports injuries and surgical procedures.

T Alsinet et al, [6] describe the medical protocols (MP) which specifies different sequences of actions that could be performed when patients are suffering from particular diseases and depending on clinical results.

Stefan Kirn et al,shows the increasing need of ubiquitous healthcare. The mobile assess has been increasingly popular among individual healthcare consumers. The advance healthcare need to be patient centric and capable of capturing, storing , maintaining and retrieving patient health related information at the moment. He developed a mobile architecture involving macro level, micro level and co-operation protocols. His inference model is capable of controlling system behavior and capture and generates the information as and when required [8].

Jiang Tian et al,tell about the four areas of e-medicines i.e. (1) lifetime health and medicine, (2) personalized health information, (3) tele-consultation and (4) continuing medical education. Multi-agent system can not only integrate the medical knowledge, clinical experience and make decision support, but also adapt the system rapidly to the change in environment, so multi-agent approach can effectively tackle the complexity of e-medicine systems. The focus of the study is providing the facility of the telemedicine to the patients who are suffering from diabetes [10].

Moreno, developed multi-agent systems that tackle diverseproblems, such as the management of organ transplants across Spain, the access to medical information of a cityand the intelligent management of the data of thepalliative patients of a hospital. In MAS for organ transplant and agents coordinate between themselves to find patients who need the organ transplant and are in critical stage. They divided patient's emergence in different category. Secondly he developed MAS for visitors who can obtain information about medical centers in cities in Spain. Different agents in different cities provide information to visitors like different medical centers, there timing, different departments available in centers, doctors schedule and there visiting time. Thirdly he develops the MAS to improve the management of information of the patients in palliative care unit of hospital. These patients are in advance stage of diseases. To ease the pain in the final phase of their lives medical techniques are used by seeing their daily data about amount of medicines taken, weakness in body, dizziness, drowsiness [11].

TawfigAbdelaziz et al,considered UseCase maps to explain the overall behavior and visualization of multi-agent based medical diagnosis system. They emphasized the need of understanding MAS require high level views while visualizing, understanding and defining the multiagent medical

diagnostic system behavior. They concluded that these can be achieved with the help of UseCase Maps [12].

As per literature review it is concluded that large research work has been conducted in the field of sports medicine by using various technologies. It has been seen that the focus of the researches were on diagnosing various disease such as pain in back muscles of thighs, pain in ankle, tumor detection, diabetes etc by developing graphical system using various advance technologies like XML, Neural networks and some other artificial intelligent technologies. Hence it is driven that further enhancements can be done in this field by using fuzzy logics. Because decision making in sports medicine relies on some factors and conditions therefore fuzzy logics will be more suitable technology for this as it works on the basis of rules and conditions defined by the developer while considering some factors. A fuzzy logic is a system which performs various decision making operations on the basis of various rules.

III. FUZZY LOGICS

Fuzzy is applied in various fields such as engineering, studies, medical etc in order to derive a decision. Fuzzy system is easy as well as simple to understand and implements. Fuzzy system is a logical system which is in the form of many-valued logic. The truth table of these values lies between the range of 0 and 1, since Boolean logic supports the 0 and 1 only and considers the result either 0 or 1. It also supports the elements which are surrounded by the set may either have partial degree of membership means either element belongs to a set or not. These degrees are managed by any particular functions when applied with the linguistic variables. Fuzzy use linguistic variables in addition to quantitative variables in order to present vague concept.Membership function defines mapping of a membership value between 0 and 1 in the given input space. Universe of discourse is another term used for input space [13] [19].

Following figure 3 explains the working process of fuzzy system in brief. Firstly a crisp value is added to the fuzzy system as an input. Then Fuzzification process is applied to the crisp fuzzy values. Fuzzification is a process which converts the crisp values into fuzzy sets.

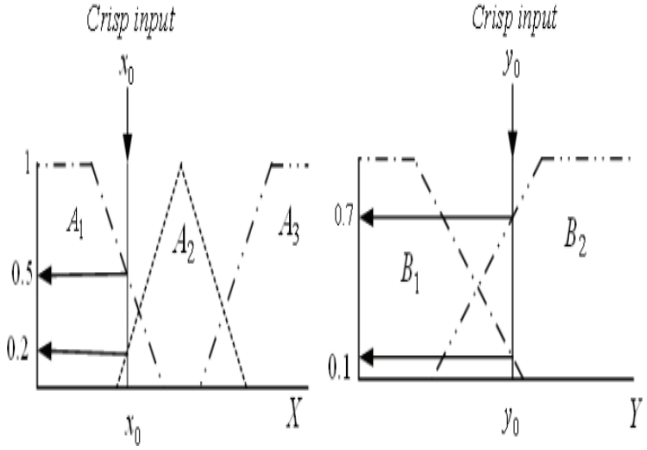


Figure2. Fuzzification[34]

Then defined rules are applied to the fuzzy input set driven by applying fuzzification. On the basis of rules an intelligent decision is taken and then the fuzzy sets are converted to the crisp values back by applying the Defuzzification.

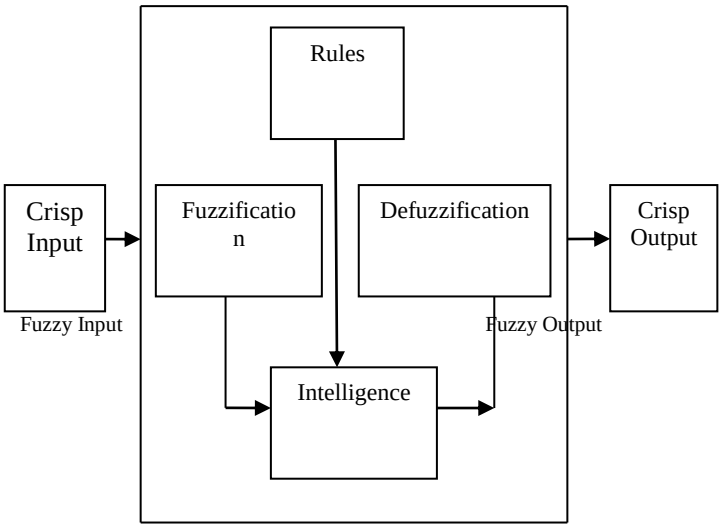


Figure3. Working of Fuzzy Logic Based System

A. *FUZZY RULES*

Fuzzy logics have dual core nature on one hand it act as a rule based system and on other side it is also a non linear mapping. In order to understand the transformation of IF-THEN rules into non linear mapping let's consider the example that we have a collection of IF-THEN rules:

$$R^{(1)}: IF\ x_1\ is\ F_1^l\ and\ x_n\ is\ F_n^l\ THEN\ y\ is\ G^l \qquad (1)$$

In equation (1) $x = (x_1, \dots, x_n) \in R^n\ and\ y \in R$ belongs to the input and output of the fuzzy logics.
$F_1^l\ and\ G_l$ are considered as the labels of fuzzy sets represented by R and $l \le M$.
With respect to fuzzy logics, each rule defines a fuzzy set as follows:

$$F_1^l \times \dots \times F_n^l \to G^l \qquad (2)$$

The membership functions can be defined as follows:

$$\mu_{F_1^l} \times \dots \times F_n^l \to G^l(x,y) = \min\left[\mu_{F_1^l} \times \dots \dots F_n^l(x), \mu G^1(y)\right] \qquad (3)$$

Or

$$\mu_{F_1^l} \times \dots \times F_n^l \to G^l(x,y) = \mu_{F_1^l} \times \dots \times F_n^l \to G^l(x,y) \qquad (4)$$

Where

$$\mu F_1^l \times \dots \times F_n^l(x) = \prod_{i=1}^{n} \mu F_1^l(x_i) \qquad (5)$$

Or

$$\mu F_1^l \times \dots \times F_1^l(x) = min_{1 \le ii \le n}[\mu F_i^l(x_i)] \qquad (6)$$

Let us assume A_x an arbitrary fuzzy set in $R^{n,}$ then according to eq^{n}(1)

$$A_x\ oR^{(l)}(y) = sup_{x \in R^n} \min\left[\mu_{A_x}(x), \mu_{F_1^l \times \ldots \times F_n^l \to G^l}(x,y)\right] \quad (7)$$

From (3) or (4)

$$\mu_{F_1^l \times \ldots F_n^l \to G^1}(x,y)$$

To understand the rule formation in fuzzy let's consider an Example of AND gate. In AND gate the input is always taken in the form of 0 or 1. The AND gate generates High output only if both of the inputs are high. The Truth table of AND logic gate is as follow (table 1)s:

Table1. Truth Table of AND Logic Gate

Input 1 (Inp1)	Input 2 (Inp2)	Output
0	0	0
0	1	0
1	0	0
1	1	1

.Hence the IF-THEN rules in Fuzzy system for AND gate will be generated as follows:

$$IF\ Inp1\ is\ Low\ and\ Inp2\ is\ Low$$
$$THEN\ Output\ is\ Low \quad (8)$$

According to this rule, if Inp1 and Inp2 are 0 then the Output will be 0.

$$IF\ Inp1\ is\ Low\ and\ Inp2\ is\ High$$
$$THEN\ Output\ is\ Low \quad (9)$$

The above rule defines that if Inp1 is Low and Inp2 is high then the Output will be Low.

$$IF\ Inp1\ is\ High\ and\ Inp2\ is\ Low$$
$$THEN\ Output\ is\ Low \quad (10)$$

Accordingly IF Inp1 is high and Inp2 is low then the output in this situation will be low.

$$IF\ Inp1\ is\ High\ and\ Inp2\ is\ High$$
$$THEN\ Output\ is\ High \quad (11)$$

This rule defines that IF Inp1 and Inp2 are high then the Output will be high

The above example defines that the output of fizzy system depends upon the input parameters and rules that are defined by considering these input parameters.

Systems used in Fuzzy logics are as follows:

1. Sugeno
2. Mamdani

a) Sugeno:

Sugeno is a fuzzy model. It works as follows:

1. Let's consider that fuzzy inference two inputs x and y respectively and generate corresponding single output z.
2. A first-order Sugeno model will have following rules:
3. Rule 1:
   If x is A_1 and y is B_1 then $f_1 = p_1x + q_1y + r_1$ (12)
4. Rule 2:
   If x is A_2 and y is B_2 then $f_2 = p_2x + q_2y + r_2$ (13)

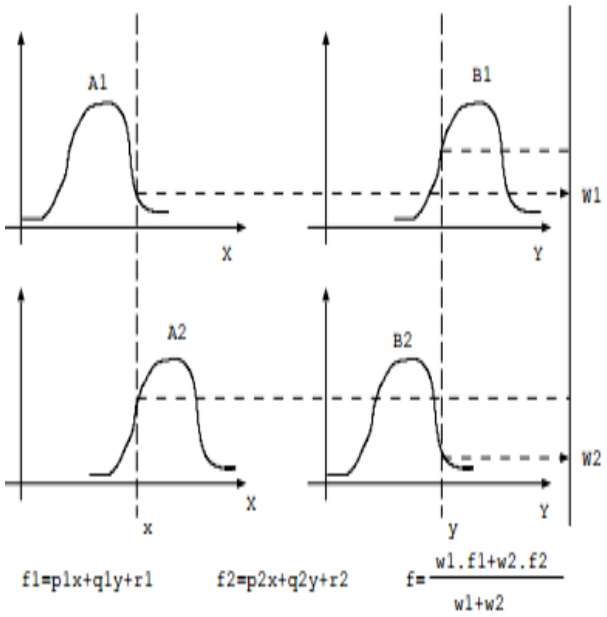


Figure4. Graphical representation of Sugeno model [34]

b) Mamdani:

It is the most commonly used fuzzy interference technique developed by Mamdani and Assilian hence named as Mamdani. In this model the fuzzy implication is applied by mamdani's minimum operator. The steps of Mamdami fuzzy interference system are as follows:

1. Apply Fuzzification to the input variables.
2. Apply fuzzy operators to the fuzzify variables.
3. Then implement implication methods.
4. Implement Aggregation process.
5. Apply Defuzzification at last.(.)

Consider an example of fuzzy inference with two inputs x and y respectively and generate corresponding single output z.

The rule defined in Mamdami fuzzy interference is as follows:

$$R_i = IF\ x\ is\ A_i\ AND\ y\ is\ B_i\ THEN\ z\ is\ C_i, i = 1 \ldots., n$$

With Triangular Membership Function:

$$\mu_A(x) = \begin{cases} 1 - \dfrac{x-a}{\alpha}\ if\ |x-a| \le \alpha \\ 0 \qquad\qquad Otherwise \end{cases} \quad (14)$$

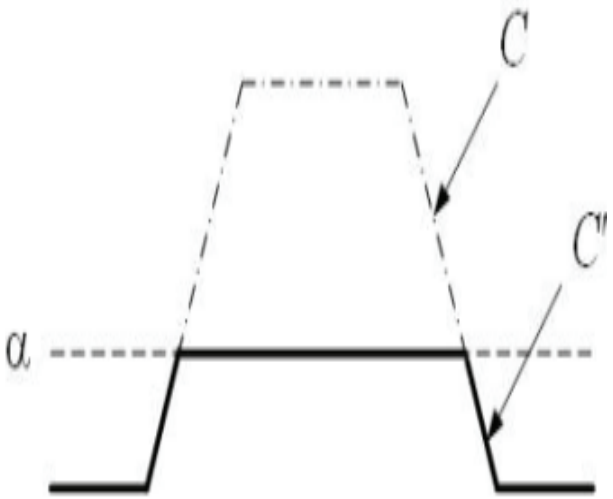


Figure5. Graphical representation of MamdaniModel [34]

IV. MOTIVATION

Now a days, Sports medicine in one of the most prominent field for research work among the researchers. Many researchers are continually working in this field to generate a suitable sports medicine system for the sports people which help them to break the bars in their way to achieve their goals. From the literature (Section 1) it is concluded that the most working area in the field of sports medicine are

1. Injuries of ankle
2. Injuries of Elbow
3. Pain in back muscles of thighs
4. Tumor detection

And it is also observed that the traditional approaches mostly grow up from the basic fundamentals approaches like XML or database basedmachine learning techniques to reach up a standard those are used these days. It is also noticed that the injuries those are covered in the literature are not sufficient since the injury related to the Knee was not considered earlier. Knee is a part of the body which helps in various athletic activities in various sports such as cricket, hockey, football etc. Hence this is a vast field for researchers to focus since zero work has been done in this. Therefore it is essential to develop such a system which provide solution or decision system for the field. Also the requirement of such a system has been arises which is based on some intelligent technology that will work as in present advance soft computing based medical applications. The invention of such trendy system can lead to resolve the various backlogs of traditional work. Soft computing is one the prominence technology used for decision making. Soft computing methods support natural systems to be combined with intelligent machines which lead to be a good system. Common method from soft computing which is used to tune the parameters of the controller is neural network, fuzzy logics etc.

V. IMPLEMENTATION

As per the literature survey, it is concluded that various researchers pay attention to the various disease and injury that happened to a sports person. Knee Injury is one of the most crucial injuries that are avoided by the sports persons. Knee is the most important part of the body which is an aid to perform various athletic activities of sports person and the basic technologies were used for developing the systems of injury detection in previous work was not concentrated on the knee injury. Hence the proposed work focused to overcome the backlogs of traditional work. The System is developed by using Fuzzy logics as the injury detection is based on some symptoms and fuzzy also works on the basis of rules. The proposed system is far cry from traditional works.

WHY FUZZY?

Fuzzy logic is best suitable technology for developing such a system where output depends upon the input given to it. As fuzzy logic is based on IF-THEN rules similarly the disease diagnosing also depends upon some symptoms. For example if a person has symptoms like headache, body pain and high body temperature only then it is decided that he is suffering from any kind of fever or viral.

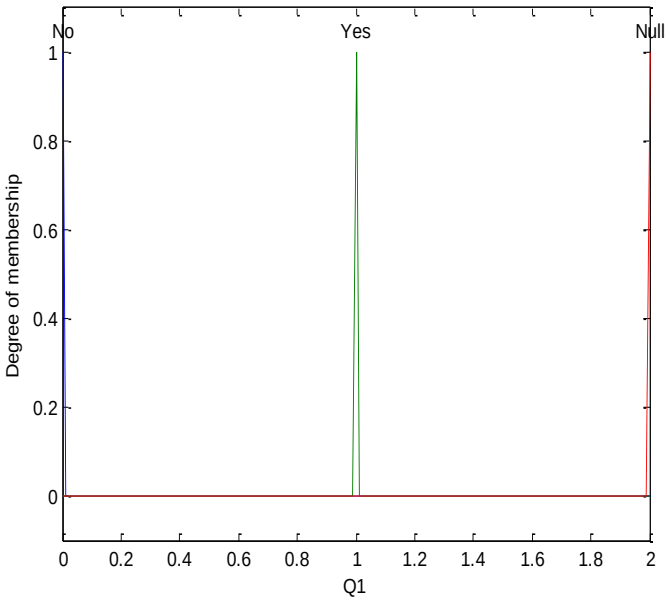
a) Rules formation for proposed work.

Fuzzy needs to enter some input to the system only then it produces some output. Hence first step is to enter some inputs to the system and then these input values are changed into fuzzy values by using fuzzification. Then after that, a list rules has been applied to these fuzzy values. Figure 5 defines the list of rules defined for designing the proposed system. It represents some Symptoms and diagnosis and shows corresponding self-care. It starts from asking the symptoms from the user.

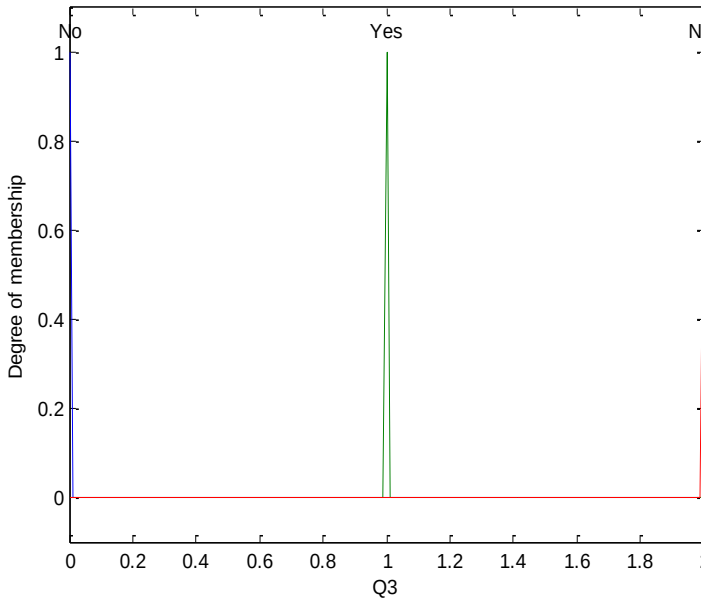
For better understanding let's consider the case 1. In this firstly a question is asked to the user i.e. Did your knee pain or swelling begin after a fall, twisting injury or after your knee hit by an object or person? IF the answer to this question is "YES" then it will proceed to the second question which again asks to the user, is your Knee deformed? And if the answer to the question 1 is "NO" then it will proceed to question 7 which again have a query for the user and if the answer is "YES" then it will lead to next query. If the answer is "NO" then it will jump to the question 9 which again ask a query to the user. And at last it will diagnose the problem on the basis of symptoms and a self-care advice will be generated after combining the symptom and diagnosed problem.

b) Define Membership functions.

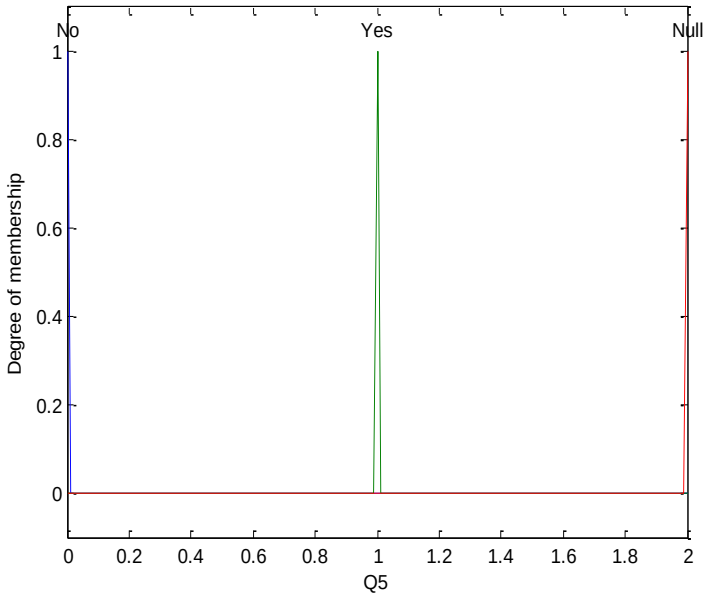
This section defines the membership functions used to implement the previously defined rules. The Mamdani model is used for implementing the proposed work. Total number of inputs to the proposed work is 10 and each input has three memberships function yes, no and null respectively. The following image defines the membership function corresponding to all inputs i.e. Q1, Q3, and Q5. Rest of the inputs will have similar membership functions as represented in following graphs.



(a)

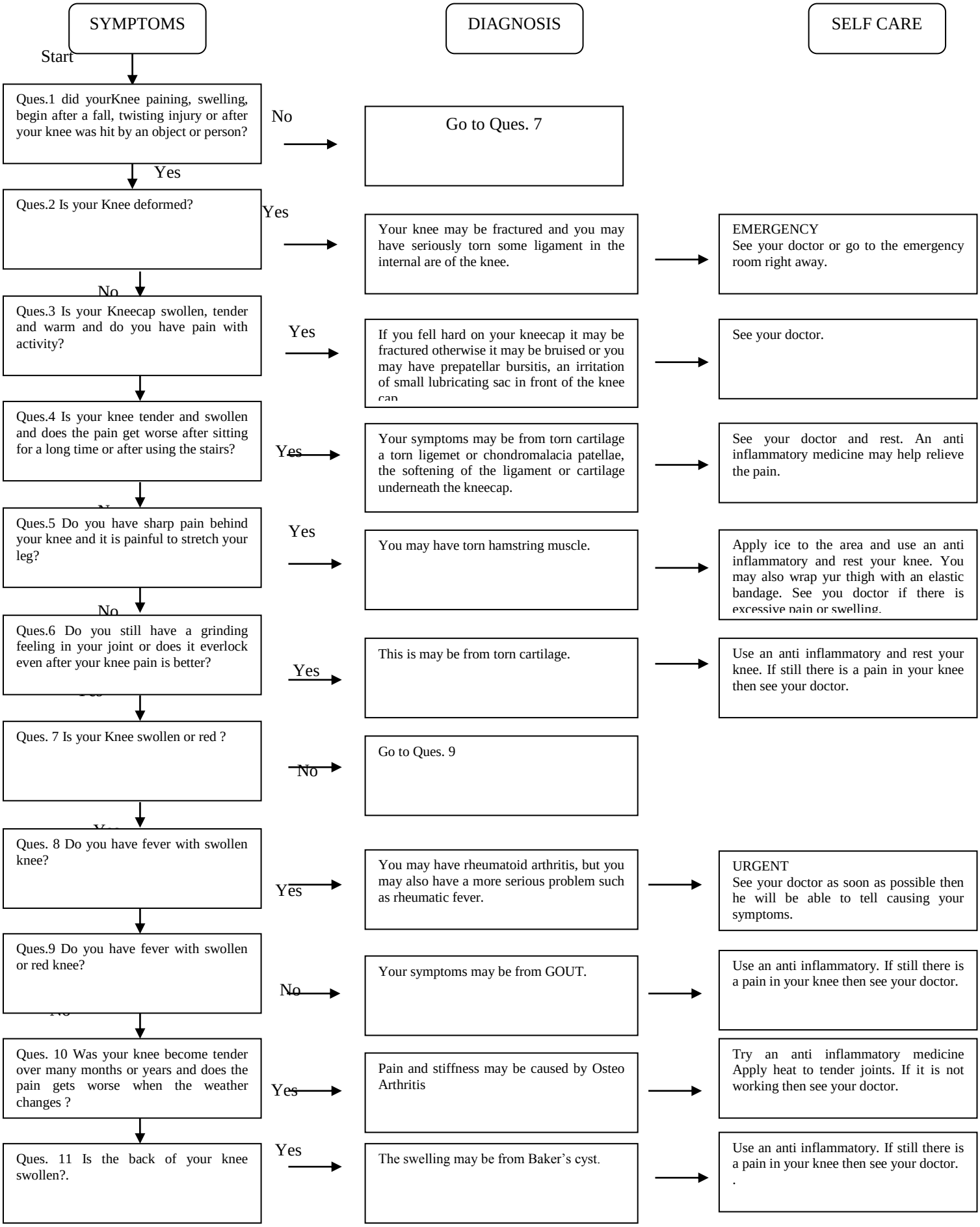


(b)



(c)

Figure 6(a),(b),(c) Membership functions used for input in proposed work



After defining the membership function the rules have been created as follows (figure 7):

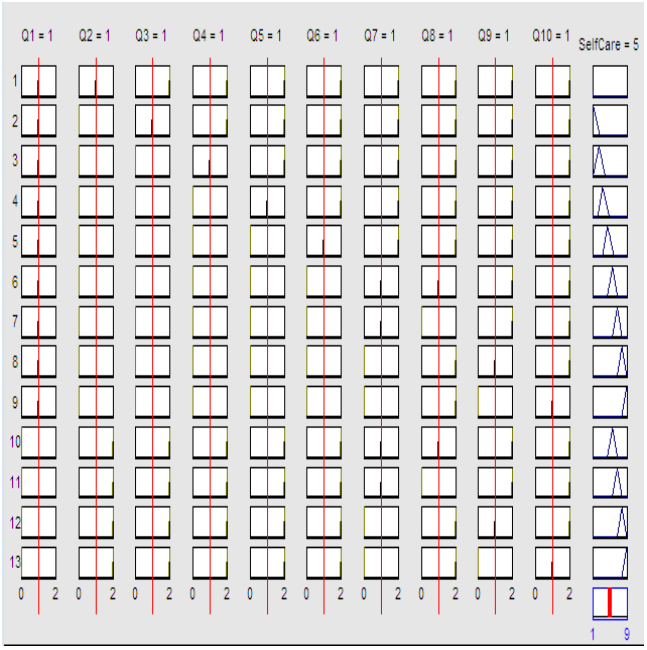


Figure7. Rule Viewer presented by the proposed fuzzy system.

The figure 8 below defines the fuzzy inference system of proposed work which takes 10 inputs and generates 1 output. The Mamdani model for fuzzy interference is used for proposed system.

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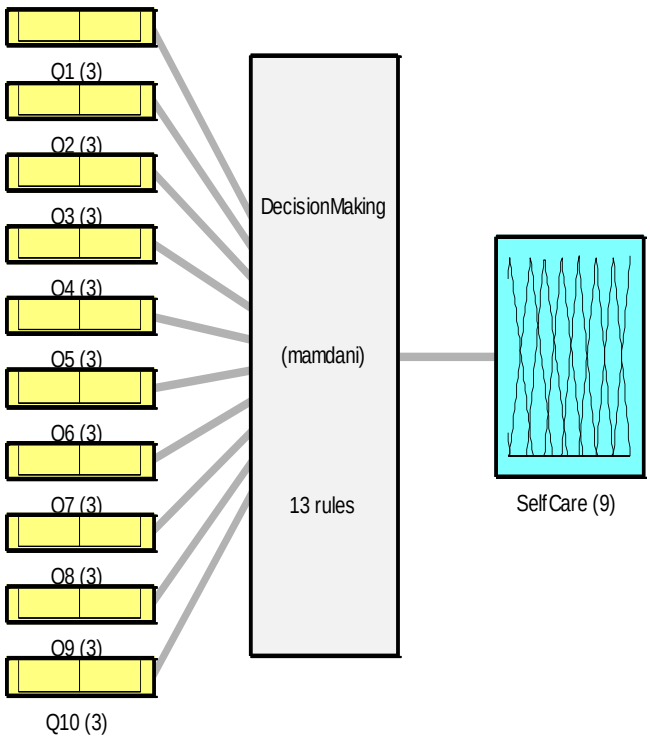

Figure8. Proposed Fuzzy Interference System

VI. METHODOLOGY

The mode of the proposed work is as follows:

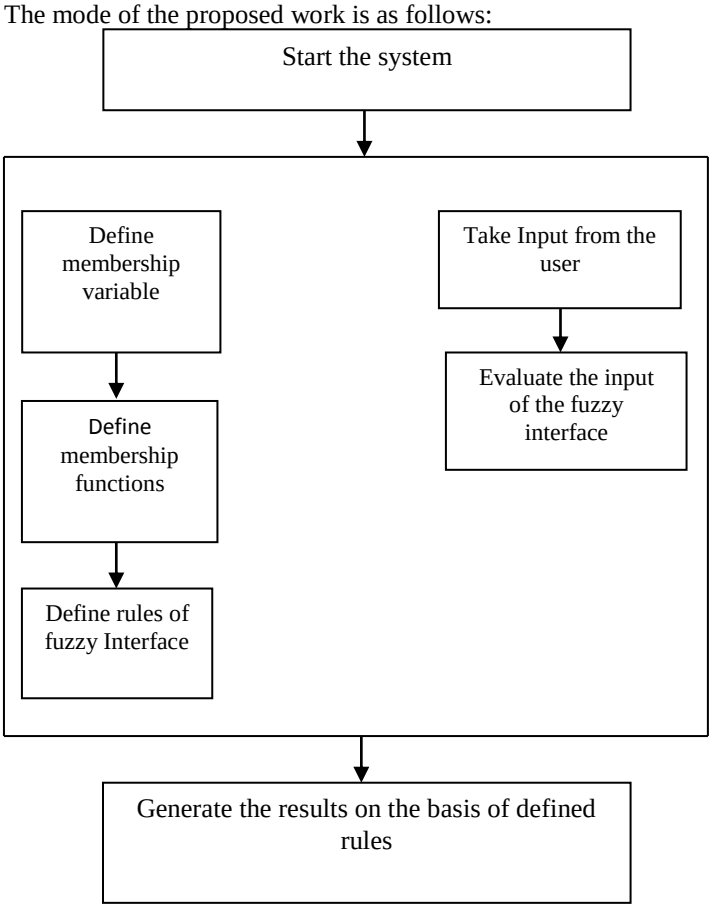

Figure9. Block diagram of proposed work

Methodology of proposed work is as follows:

STEP 1: First step is to start the system. This step is for initializing the fuzzy system.

```
{
        Initialize Parameters ();
        CreateFuzzyObject ();
}
```

STEP 2: In this step fuzzy takes the input from the user. The input is taken in the form of yes or no by asking questions to the user.

```
{
        Inp=getInput();
        fori=1 to conditions
         {
        ifInp==true || Inp==false
        move to fuzzy section;
        else
        CheckInp();
        Disp(Wrong input Message);
        end
        }
}
```


STEP 3: Next step is to design the fuzzy system. In this step first of all membership variables are defined which leads to the creation of membership function further. After creating membership functions next step is to creating the rules for fuzzy system.

```
{
        FuzzySys=fuzzy('NameFuzzySystem');
        Inputs=n;
                for I =1to n
                {
                define Membership Variables;
                define Membership function;
                  }

        Ruledefine ();
        Combineruletofuzzy();
}
```

STEP 4: Evaluate the input received from the user on the basis of designed rules of fuzzy network.

```
{
          Inp1=user_defined();
          Inp2=user_defined();
          Inp3=user_defined();
          ||||||||||||||||||||
        ||||||||||||||||||||
        InpN=userdefined();

        Loadfuzzy();
          For i=1 to Inputs
          {
        Fuzzyeval();
        }
}
```

STEP 5: Last step is to represent graphical results on the basis of evaluation performed in previous step.

VII. EXPERIMENTAL RESULTS

The working of proposed work is defined in this section. The image below (Figure 10) defines the GUI (Graphical User Interface) of proposed work. It has 4 buttons placed on it. START SYSTEM button is used for starting the fuzzy system. DESIGN FUZZY SYSTEM is used for designing the fuzzy system on the basis of input taken from the user. EVALUATION is used to generate self-care advice on the basis of diagnosed problem.

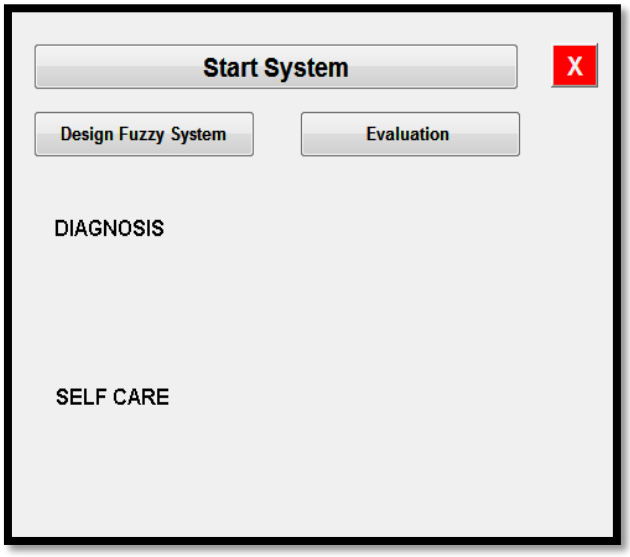

Figure10. Graphical User Interface of proposed work.

When user click on Start System button. A dialogue box will open asking the user for the symptoms. And after this user has to click the suitable button i.e. YES or NO. Suppose user click YES button then as per defined rules it will proceed to the question.

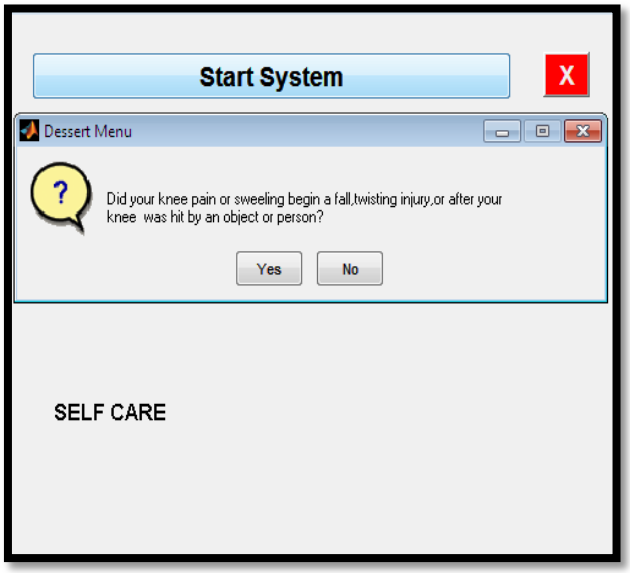

Figure11. First query generated for user related to the symptoms of the disease

In figure 12 second query has been shown. Here again user have to select the suitable option. If the selected option is YES then according to defined rules it will generate the self-care advice to the user. After this step no more queries will be generated in next step.

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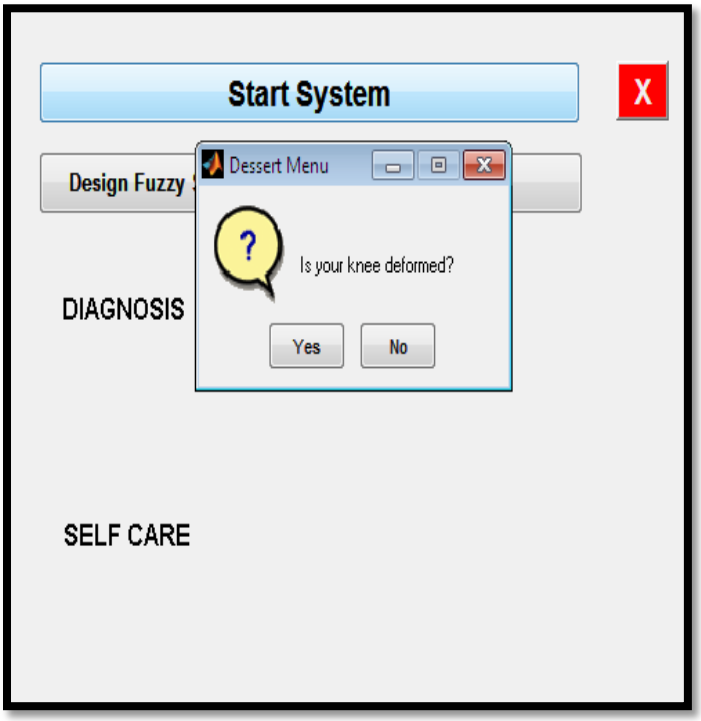

Figure 12Second query generated for user related to the symptoms of the disease

The figure 13 shows the result or self-care advice generated by the system after having inputs from the user and applying fuzzy operations along with the defined rules.

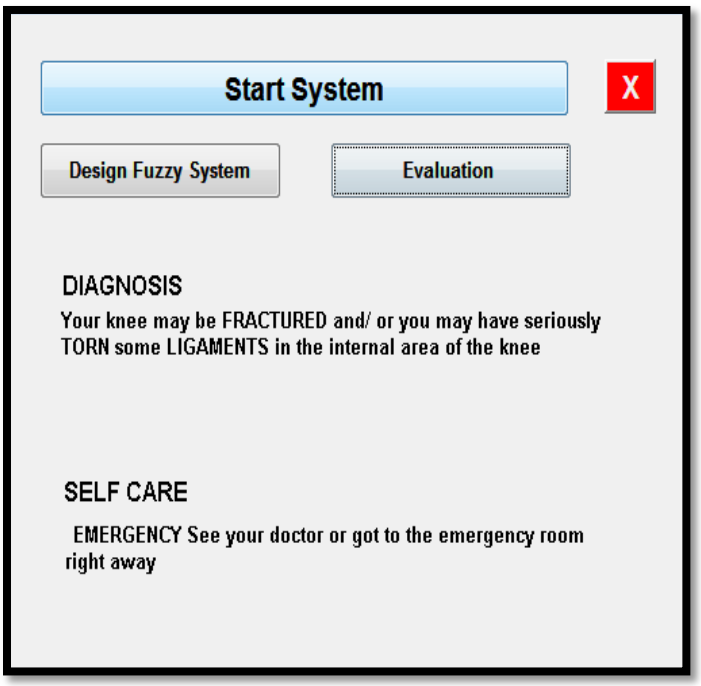

Figure 13 Self Care advice generated by the system after proper evaluation.

The results generated in this are based on the rules defined for the fuzzy system. As per rules if the answer corresponding to first question is "YES" then the system will ask for second question. If the answer to second question is "YES". Then the system will diagnose the problem on the basis of both queries and will generate a suitable self acre advice to the user.

Table2. Parameters Used In Fuzzy

Type (Input/Output)	Parameters	Member Ship values
Input	Paining Swelling Knee Tender Sharp Pain Behind Your Knee Fever	No–trimf Yes–trimf Null–trimf
Output	Possibility of Knee Injury	Decision of disease represented on scale 1-9

Table 2, represents the input and the out variable and their membership function related information. The membership function used in the proposed work is triangular which is decided as inputs in the proposed work are either yes or no means are a type of questions that will be taken from the user to take decision regarding the possibility of the knee injury.

VIII.CONCLUSION AND FUTURE SCOPE

It has been found that various enhancement is done in the area of sports medicine in order to achieve high level performance with respect of reliability and accuracy of the output generated by the system. But the work done in previous study is not much satisfactory now days. There are various backlogs behind the failure of the traditional work such as the injuries of major body part i.e. knee were ignored and another problem was the technique which wereadopted for implementing the work.

Knee injury diagnosing is done in this work by using the latest technology i.e. fuzzy systems. The fuzzy system works on the basis of rules and assumptions which are created by the user at its own. The system takes multiple inputs in the form of symptoms from user and correspondingly generates single output i.e. self care advice on the basis of defined rules i.e. if a person has particular symptoms then he is suffering from a specific disease and he should have precautions and medicines.

As the current technique is adopted by this study to implement an independent system in order to diagnose the knee injuries in a person. Hence selection of such an advance technique can become an aid in further enhancement in this field. In future there is no need to start from scratch in order to make enhancements in this field.

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