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Diagnosis Blood Test for Liver Disease using Fuzzy Logic

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Abstract

Most commonly lab test used to measure or monitor general health and liver health are following: Liver Biochemical/Function test, CBC and Chemistry Panel. In this thesis we are focusing on CBC. Complete Blood Counts measure the four components of blood leukocytes, Hematocrit, Hemoglobin and Blood Platelets. For this purpose we design fuzzy control model which help to diagnose a disease related to human liver. Fuzzy design model have four input variables (leukocytes, hematocrit, hemoglobin, blood platelets) and three output variables (infection fight, anemia and thrombocytopenia). Fuzzy design model algorithm divided into four steps Fuzzification, Inference Engine, Rule selector and Defuzzification. Each input variable and output variable graphically represented by MF's and regions.

Fuzzifier takes the crisp values of four input variables [leukocytes, hematocrit, hemoglobin, blood platelets] and gives the eight linguistic variables as output. As input variables maps with the MF's in two regions that's why four input variables have eight linguistic variables. Fuzzy control model input variable are independent so we have minimum twelve rules. The output of fuzzifier becomes the input to inference engine. So inference engine takes eight input values from fuzzifier and use min max method (AND Operation) and output R value; Mamadani-min process is used for generating R values.

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Rule selector gives singleton value of output function on the basis of rules; design model have twelve rules so Rule Base gives twelve singleton values. Defuzzifier takes twelve R from inference engine and twelve S from rule selector; in short defuzzifier takes twenty four inputs from inference engine and rule selector. Defuzzifier uses center of average method $\sum Si \times Ri / \sum Ri$ and gives crisp value as an output. Metlab tool is used for plotting graphs and simulation. Error difference between simulated and calculated values is less the 1.8% which is acceptable. The design system can be extended by including the factor of ALT, AST, Alkaline Phosphatase, GGT, GGPT, Bilirubin, Albumin, prothrombin time, electrolytes, Glucose, Lipids, BUN, Creatinine, and uric acid.

Keywords: Fuzzy Logic; Fuzzy Logic Control; White Cells ;Hematocrit; Hemoglobin; Blood Platelets; Medical Diagnosis Control System; Inference Engine; Rule Selector; Membership Function; Center of Average

1. Introduction

1.1 Background

1.1.1 Fuzzy Logic - An Overview

Lotfi Zadeh in 1965 while developing fuzzy set theory emerges the concept of fuzzy logics [1,2]. Fuzzy logic consists of probabilistic logic or many valued logic. Rather than fixed and exact reasoning it provides approximate reasoning. Fuzzy logics can have varying values instead of fix values. Binary sets consist of two-valued-logic which is true or false, whereas fuzzy logic consists of different values (truth-value) ranges from 0 to 1. This concept of fuzzy logic is being extended for the conception of partial truth. Truth values may have entities in between completely true or completely false. Fuzzy logics are being used in different areas from control theory to artificial intelligence. Probability and fuzzy logic are being used as different ways to express uncertainty. Fuzzy logic which is based on fuzzy set MF's which basically discuss how many times a variable is in the set, while theory which is based on the notion of individual probability is called probability theory and it discusses the probability of the variable to be in a set. Fuzzy logic consists of two distinguished directions. One is fuzzy logic in the broader sense, is better known, older and instead of giving deep logic questions is being heavily applied, mainly attends as apparatus in several application areas of fuzzy control and natural language processing. It is also being used in the area of soft computing to give sufficiently good, simple and quick solutions. Symbolic logic is considered to be the fuzzy logic in the narrow sense, which is relatively young, developed in contrast to the classical logic which is based on semantics, completeness, syntax, truth preserving and axiomatization.

1.1.2 Fuzzy Rule based System

Fussy rule are based on linguistic rules which are IF-THEN. Generally it construction is represented as "IF A THEN B" where A (premise) and B (consequence of the rule) are linguistic variables. Infect tolerance in the uncertainty and impressions are exploited by fuzzy IF-THEN rules and linguistic variables. According to this fuzzy logic copycats the vital capability of the human mind to precise data and focus on information related to decision.

1.1.3 Fuzzy Inference Engine

In fuzzy logic, fuzzy inference is used to formulate mapping of given input to output. Further decisions are made on the basis of this mapping. Fuzzy inference engine is basically based on logical operations, MF’s and if-then rules. In the toolbox one can implement fuzzy inference system in two ways which are Mamdani and Sugeno. These types differ in the method of determination of output from the input. Fuzzy inference systems are successfully being applied in different domains of interest such as data classification, expert systems, automatic control and specially in computer vision. Due to the multidisciplinary nature it is being associated with fuzzy rule based systems, fuzzy modeling, fuzzy logic controllers, fuzzy expert systems, fuzzy associative memory and both for simple and ambiguous fuzzy systems.

Fast Fuzzy Inference Systems (FFIS) are the resultant of optimized and portable implementation of Fuzzy Inference Systems and supports both method of Mamdani and Takagi-Sugeno. FFIS provides a feasible high-level C++/API. Also additional useful features have been implemented such as:

- Fastest possible FIS implementation of Mamdani's model
- High-Level feasible C++ API providing readability and ease of maintenance
- Generic design providing more flexibility and control over inference engine
- Platform-independent implementation and build system
- MATLAB FIS Integration (Import from and Export to)

1.1.4 Fuzzy Logic Control System or Fuzzy Diagnostic system

A fuzzy control system (FCS) is based on fuzzy logic. Instead of classical or digital logic which is based on discrete values of either 1 or 0, fuzzy control system is a mathematical system use to analyze the input values on continuous values between 0 and 1 in terms of logical variables.FCS is designed on the methodology of trial and error which is an empirical method. The general method proceeds as:

- Preparation of the documents consists of input, output and system’s operational specification.
- Prepare the input of the fuzzy set.
- Documentation of the rule set.
- Declare defuzzification of the method.
- According to the requirement run the test suite validate system.
- Documentation should be released for the production.

1.1.5 Explanation of input parameters

We have four input variables. Table 3 shows four variable white cells, red cells [Hematocrit], red cell [Hemoglobin] and blood platelets. The given table discusses the different ranges of inputs variables.

Table 1.1 Complete Blood Count Test Chart

	Blood Cells	Normal Range	High Count	Low Count
1	**White Cells [Leukocytes]**	4,500-11,000/cu MM	Actively fighting an infection	Ability to fight infection is impaired
2	**Red Cells [Hematocrit]**	41-53%	-	Anemia
3	**Red Cells [Hemoglobin]**	13.9-16.3 g/dL	-	Anemia
4	**Blood Platelets**	150-350 K/cu MM	-	Thrombocytopenia

1.2 Research Objectives

Design Blood tests for general/Liver health to enhance the diagnostics ability for the treatment of Anemia, infection fight and Thrombocytopenia.

1.3 Statement of the Problem

Blood tests for the diagnosis of the Anemia, infection fight and Thrombocytopenia diseases.

1.4 Hypothesis

Fuzzy Logic Systems can be used to Design Blood tests for general/Liver health to enhance the diagnostics ability for the treatment of Anemia, infection fight and Thrombocytopenia.

1.5 Dissertation Organization

This study consists of four sections. First section highlights the basic introduction and importance of fuzzy logic. Second section of this study demonstrates the medical diagnostic control systems which are based on fuzzy logic. Furthermore it also discuss the input and output variables required to develop such a system by highlighting the advancement in the area of fuzzy logic. Section three discusses the proposed methodology in this study and environmental setting of the input and output parameters required for the simulation of the proposed model. Fourth section discuss results of the simulation and outcome of the simulation which are rules developed for the diagnostic of the disease.

2. Literature Survey

In the development of medical systems, since 1980s, fuzzy logic is being extensively used. In the last few decades the significant development of control system theory can been witnessed by which development of computers and electronic has outcome into many different application of control system theory [3]. As its clear that area of medicine is not directly related to control engineering but being affected by the available control engineering techniques for online devices which are being especially used in intensive care units and during surgical operations [4,5,3].Zadeh in 1965 developed Fuzzy set theory through which different inexact medical entities was easier to be defined as fuzzy sets [1,6,7]. The excellent approach of Fuzzy set theory can be used in the different optimization problems e.g approximating medical text. In approximate inference fuzzy logic also provides different reasoning methods. In 1970 from the origin of fuzzy set theory two different sub areas were initiated. Fuzzy relations were introduced by Sanchez and on the other hand Assillian and Mamdani initiated fuzzy control[8,9,7]. Fuzzy relations modulate the medical knowledge to express different relations/association among different diseases and corresponding symptoms. Fuzzy control emphasizes a control system capable of working with sentences instead of equations. In the area of medicine different application of fuzzy set theory are recognized for characterization of real world knowledge by incompleteness, inconsistency and inaccuracy[7]. In the recent decades different intelligent systems are being developed in the areas of computational intelligence to solve complex problems. For decision making Fuzzy logic is considered to be the powerful tool for the development of different expert systems which may be either medical expert systems or system used for the classification of different patterns. Irrespective of the traditional rule-based approach, fuzzy logic is a powerful tool in the area of intelligent systems for the design of intelligent knowledge based system to solve complex problems of medicine. Before discussing suitability of fuzzy logic and set theory for the handling and representation of different medical concept one may discuss different concepts of fuzzy logic. Logic discusses the notion of consequence by emphasizing set of preposition and relationship among different consequences. Formal logic uses well defined different logical calculi based on definition of sentences and notion(s) of consequences (predicate logic, many-valued propositional/predicate logic, modal propositional/predicate logic, and propositional logic) by admitting exact investigation for the representation of consequences and corresponding relationship. Logical calculus consists of two different notion of consequence. One is syntactical, and second is semantical which are based on notion of proof and truth respectively. In the area of medicine, fuzzy logic is elaborated by two meanings which are wide and narrow. According to Zadeh, narrow sense of fuzzy logic (FLn) aims to formalize the approximation in the reasoning [6,1,10]. Narrow fuzzy logic (FLn) is the extension of multivalued logic but differs from its traditional ways. Fln usually focus on different concepts fuzzy if-then rule, the conformational rule of implication and incorporative reasoning, fuzzy quantification, linguistic variable and the extension principle are discussed by the traditional systems based on multivalued logics [10]. Due to these reasons FLn is being used in most of the wider range application based on traditional systems. On the other hand, fuzzy logic wide (FLw) is identical with fuzzy set theory (FST). Fuzzy set theory consists of classes with un-sharp frontiers and much broader then FLn. Zadeh opinion may be concluded by two things: one which is broader sense, fuzzy logic is the everything which is dealing with fuzziness and second is narrow sense, according to which fuzzy logic is based on multivalued logic [6,1,10]. According to fuzzy logic most medical concept in oriental medicine are fuzzy. However, “fuzzy 3 logic” can be used in the rough nature of medical concepts and their relationships. Fuzzy 3 logic provides fuzzy sets by inexact medical entities and it also describes linguistic approach having great approximation to text. “Fuzzy logic” proposes reasoning approaches capable of sketching estimated extrapolations. Oriental medicine provides rules which are difficult to formalize and measure like “severe pain”. On the other hand, tradition mathematics provides well-defined properties P(x) which are either true or false. Each defined property defines a set: {x | x has a property P}. To formalize non-crispy properties, L. Zadeh proposed a theory in 1965, according to which one can define crispy property by the charcterist function $\mu: X \rightarrow \{0,1\}$[6,10].For different objectives fuzzy set theory was generalized in which interesting and useful generalized technique is intuitionistic fuzzy sets (IFSs) proposed by Atanassov [1,2,3]. It's been argued that vague sets are nothing but IFSs [4,5,3]. This IFSs theory was applied in decision making problems [6], logic programmingetc [1,2,3]. Fuzzy logic theory is the extended version of binary logic theory by considering the logic of reasoning, thinking and inference capable of recognize by incorporating real world phenomenon which consists of everything is the matter of degree. Instead of assuming that everything is white or black, it presumes that everything is in between white and black. By representing the system information in binary form which increases the complexity of the system. So the extend version of binary logic theory which fuzzy logic is very computationally effective through the use of fuzzy sets [7,8]. According to traditional set theory something either belong to a set or net but in fuzzy set theory something have different values so it can also belong to more than one set at a time. So something in fuzzy set theory can be partially part of a fuzzy set having a degree of membership between one and zero but the total membership adding to one. Fuzzy set can be represented by different shapes including sigmoidal, irregular, and triangular or bell shaped, but often by trapezoidal [9]. In order to represent fuzziness better, recently, concept of type II fuzzy set was introduced in which border of fuzzy sets was represented by lower and upper bound instead of one line [8]. It is difficult to mathematically model a nonlinear system but fuzzy logic, can be used to monitor, and based on continuous variables and set theory. Fuzzy logic can be used in different application of control, household appliances, automobiles and decision making systems by using the vocabulary of fuzzification, member function, domain, defuzzification, linguistic variables and rules etc. the fuzzy logic control systems and expert system have the same ground. The difference lies in the sense that expert system cannot handle difficult processes while ambiguous process can be handled by the fuzzy logic control systems. Fuzzy logic control systems instead of human operator uses linguistic rules. Strategy of the user can be clearly defined by these linguistic rules. Fuzzy expert systems use member function to get the result or the conclusion and based on the IF-THEN rules. Member function and input-output pattern depends upon the two factors which are designers experience and information. Diagnostic systems are used to control the behavior of a process and predefined patterns. Diagnostic systems which are basically a form of expert systems are used to control suggestion for a certain treatment after identification. Fuzzy logic is being used in the different diagnostic systems for the treatment of cancer and diabetes [10].DIAGAID software was developed by Turku University Hospital which is based on fuzzy logic [10]. Ch. Schuh and his colleagues demonstrated the used of fuzzy logic in the development of different human health care systems and in the medical data of different patients [11,10]. M. Mahfouf, M. F. Abbod, D. A. Linkens and his colleagues on the basis of facial expression and human behavior describes how one can use fuzzy logic to solve different problems of neuro-medical field [10]. For human health, Practical application of different management system is demonstrated by Yataka Hata, Syoji Kobashi and Hiroshi Nakajima and his colleagues they contributed a lot to generate schemes for the health management and medical diagnostic [10]. Immune system, which on the basis of immune algorithm consists of fuzzy cognitive maps and flow chart, is used to protect the human body was illustrated by HeYue , GuoYue and Guo Yi and his colleagues[10]. Christian J. Schuh and his colleagues conduct a survey regarding the applications of fuzzy sets, fuzzy controls, relations and fuzzy logic in the development of medical diagnositic expert system. Gluco Notify was also been explained for the different concepts of ARDS therapies such as fuzzy automata and patient glucose data setting [11,10]. Intuitionistic fuzzy set theory was introduced by Supriya Kumar De, Ranjit Biswas and Akhil Ranjan Roy and his colleagues [10]. This idea was further used to check the probability of the occurrence of the brain tumor and it also discusses the probability of the normal results [10].Researchers from area of computer science are developing different applications for the different fields related to medicine and even to health sciences. Artificial intelligence is actively involved in the development of applications for the medicine and health sciences [12]. Many support systems for clinical decisions have been developed in the area of artificial intelligence for the medical support in the decision. To have these supporting systems different methodologies are being used. How to create and utilize clinical knowledge is one of the features of artificial intelligence [12]. Apart from this clinical expert system which is based on AI approach can learn and create new knowledge. In clinical support systems AI is supposed to be the integral part which can adopt new clinical knowledge from the environment for further decision making [12]. Various AI methods including statistical methods, neural networks, knowledge based methods, fuzzy logic rule based and genetic algorithms are being used in the development of Expert Systems [12]. The selection of method depends upon various aspects including domain of the problem, purpose of the researcher, solution to the problem, choice and amount of input data available [12].In medical science researcher are in the need of computer aided software for the diagnosis of pain such that these software can transform health related signals into pan intensity [12]. As the patients become worse due to the degradation of patients life and proper evaluation patients stop asking for further medication [12]. In the critical monitoring of patients life after the operation needs accurate measurement of medication as the over dosage may cause threats to life [12]. To diagnosis and measure the intensity of pain clinical decision making expert systems are effective, efficient and economical. In the surgery now a days these decision making expert systems are commonly being used, in which, for operations minimal invasive surgery being preferred by the surgeons. Surgeons are now capable of bringing laser beam transendoscopically in the cavities of the body are due to the development of the wave guide or reliable flexible fiber. Transendoscopically creates powerful tool for the operating procedures by combining the endoscopy technique and laser interaction which is lower cast, minimal post-operative pain and fastest healing [12].

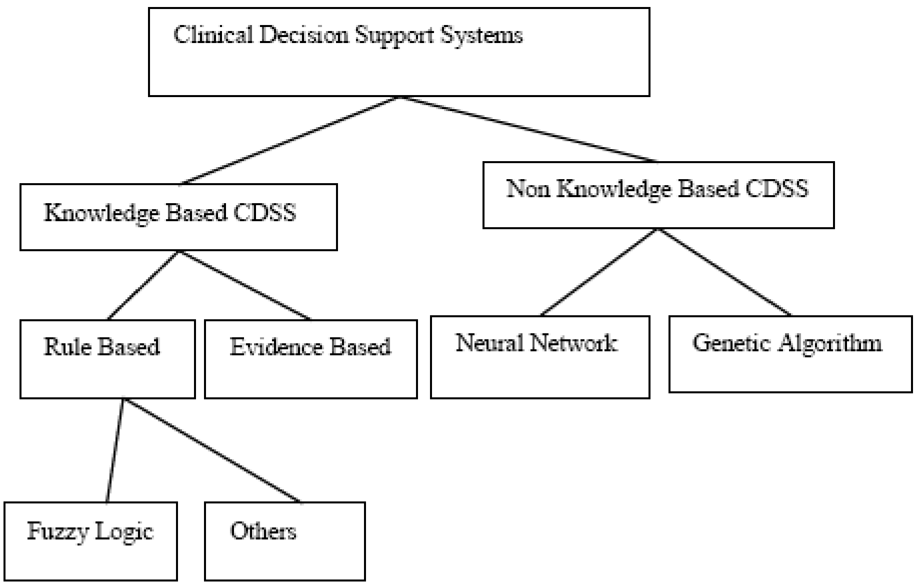

Fig 2.1 Branches of the Clinical Descion Support System

In the area of mathematics, for formal reasoning, logicians have formulated First Order Predicate Logic (FOPL). In 1960, computer based information was used to represent application of logic in knowledge by the researchers of Artificial intelligence. Human belief and uncertain knowledge cannot be represented by to valued logic e.g. predicate logic and propositional logic [13]. For this purpose fuzzy logic performed well. In fuzzy logic for the exact meaning of the knowledge Fuzzy quantifies are being used to represent disposition restoration [13]. A formal system has the following connectives: ∧ (and), ∨ (or), ¬ (not), ⇒ (implies), ⇔ (iff), and at least two quantifiers ∀ (for all), ∃ (there exit). The primitive symbols∧, ∨, ¬ and ⇒ can be used together with propositions to make up sentences and these are valid sentences (followed by specific rules of inferences) [13]. Fuzzy relations, fuzzy sets and fuzzy control in medical fields, fuzzy set theory assumes that most of the natural phenomenon is fuzzy rather than crispy in nature. Lotfi Zadeh in 1965 assumes, by generalizing of the usual set theory, that an object can be a member of more than one group rather to be the member of only one group. Following Fig 2 shows the characteristic function of a set M and membership function of a fuzzy set A.

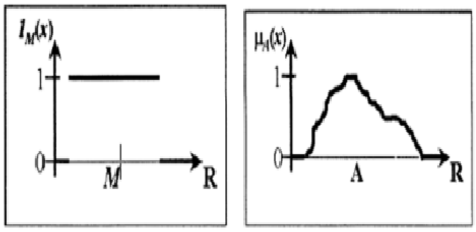

Fig 2.2 Characteristic Function of Set M and Membership Function of a Fuzzy Set A

In 1980, computer- assisted DIAGnostic (CADIAG) system was established by the researchers of University of Vienna Medical School with the collaboration of Vienna General Hospital, in which medical knowledge have been model by showing associations among different symptoms and diseases [14,11].Medical data of the patient collected by the physician may be characterized by the fuzzy logic and it may be able to ignore the medical history of the patient. A surgeon may be failed to define the patient normal or abnormal as there is no any defined criteria [15]. Even the laboratory test cannot also clearly define the patient as normal or abnormal due to imprecise and incorrect data which emphasize that there is no any kind of border line for defining normal or abnormal [15]. So according to fuzziness real world can be characterized by inaccuracy, incompleteness and inconsistency [15].Monitoring in medical and fuzzy control argues that classes may perform a key role in the thinking process of humans[16]. Through this concept fuzzy set theory is developed according to which these classes are fuzzy rather than crisp in nature. Due to tolerance to some imprecision fuzzy logic is very keen towards complex systems in which massive information is being handled and function is effectively [16]. Fuzzy logic can be seen as a tool for developing medical application to generate approximate reasons behind the disease rather to be exact [17]. In this regard number of contribution have been made by the researchers from the emerging fields in the form of software development by using fuzzy logic, fuzzy set theory that could assist a physician to generate approximate reasoning behind the symptoms of the patient [17]. These computer software and hardware based fuzzy logic based applications are commercially available and being used in the treatment of the different diseases which can be seen anywhere in the world [17].For Medical applications researchers are using fuzzy logic in which for medical decision making much of the uncertain information is required. In the area of medical knowledge based expert system were developed since the introduction of fuzzy logic by Zadeh [18,7,19]. These knowledge based expert system somehow are dealing with the uncertain information required for medical decision making with some fuzzy logic directly or indirectly [20]. Approaches other than fuzzy logic for approximate reasoning are more adhoc in nature.

In an uncertain environment learning is an important aspect which can be used for the development of fuzzy logic based knowledge system. Moreover fuzzy logic systems can be used for the management of the associated uncertainties of the linguistic expert system. Mendel introduced the idea of uncertainties based knowledge system[20]. For tackling of the uncertain information, these kinds of system use type-2 fuzzy logic which is based on noisy measurement, inter and intra uncertainties, imprecision in the input data, none stationary features and perceptions [20]. This type-2 fuzzy logic for uncertainties uses footprint of uncertainty (FOU) and three dimensional type-2 member function (T2MF) [20]. Rule sets and member function are two basic things which can affect the fuzzy rule based expert system. In fuzzy rule based systems there are three basic types of common rules. These rules can be used for the problems of the pattern classification. In the mathematical model and training data set can be captured by the rule type-2 fuzzy logic systems [20]. T2FLS can be used for the deterministic decision making in the sense of class labeling and degree of the certainty of the rules [20].The imprecision of the training data set can be used to estimate the degree uncertainty. A Genetic Fuzzy Approach for Rule Extraction for Rule-Based Classification with Application to Medical Diagnosis [20].Formal logic based on binary input and output in the form for yes or not. Instead of this fuzzy logic accepts the intervals of input and output which is non —conventional approach [20]. For the development of the medical expert system much of the biological variables can be expressed in the form of intervals instead of binary input or output. This features of fuzzy logic capabilities it to use for the development of the medical expert system for the medical decision making [20]. Now a days this concept of fuzzy logic is well established among the community of the engineering discipline. It is being used to control wide variety of the engineering devices. This is also being used to control the conventional algorithms based on the mathematical model of the system under study. So fuzzy logic can and being used in the areas where it is impossible to precisely define mathematical model of the system. Natural language by its nature based on fuzzy logic as many of the doctors demonstrate treatment of diseases, diagnoses and symptoms in natural language, whereas fuzziness is inherited from the medical procedures. HEMANAKYSIS is good example which can provide life study, quantitative analysis and early diagnoses of the many different diseases [21]. For Screening and Blood count two things are required by the hematologist [21]. One is Complete blood count (CBC) and second is differential blood count (DBC) [21]. CBC can be done automatically by using cytometer, whereas DBC, is highly complex, time taking and tedious, done by hematologists manually by using microscope [21].A fuzzy controller, based on the designed if then rules by the expert to control the system, consists of four basic parts (1) a rule base, (2) a fuzzy inference mechanism, (3) an input fuzzification interface, and (4) an output de-fuzzification interface. The outcome is fuzzified from its numeric value to fuzzy states [22]. Then these fuzzy states forwarded to the fuzzy controller [22]. These fuzzy controllers are designed to derive the infusion pump by if- then rules and expert's experience and knowledge about controlling the variables so that it can generate reasoning [22]. By mentioning the required characteristics for the controller enhance the concept of the automatically determination of the fuzzy rules [22].In the area of artificial intelligence there exist many techniques for the representation of the knowledge e.g. semantic networks, statement, production rules, logic, frameworks, and casual cognitive maps among others. Possibility theory and fuzzy logic are the two main topic of the AI community representation of uncertain knowledge and to approximate reasoning. The use of the techniques only depends on the user's skills and nature of the application.

3. Simulation and design model

3.1 Introduction

In this section; the proposed model and its simulation is discussed. Three types of lab test are used to monitor general health and liver health. But we are focusing only on the Complete Blood Count test [4 factors] in our thesis. [Liver bio and chemistry panel can be included for the future work.]

- Liver Biochemical function tests
- CBC
- Chemistry Panel

3.2 Design of fuzzy logic system

Design model divided into five steps; Step-1: Input and output variables are identified and corresponding meaningful linguistic states are selected by expressing with the appropriate fuzzy logic.Step -2: Uncertainty in the associated measurement is introduced by the fuzzification function. Step -3 Generate RulesStep -4 Inference Engine Step -5 Defuzzification.

3.2.1 Design Algorithm

The model was designed by using four different fuzzy input variables. Table 3.1 explains the MF of the four input variables white cells, red cells [Hematocrit], red cell [Hemoglobin] and blood platelets.

Table 3.1:MF's of input variables; white cells, red cells [Hematocrit], red cells [Hemoglobin], platelets.

	Blood Cells	**Normal Range**	**High Count**	**Low Count**
1	**White Cells [Leukocytes]**	4,500-11,000/cu MM	Actively fighting an infection	Ability to fight infection is impaired
2	**Red Cells [Hematocrit]**	41-53%	-	Anemia
3	**Red Cells [Hemoglobin]**	13.9-16.3 g/dL	-	Anemia
4	**Blood Platelets**	150-350 K/cu MM	-	Thrombocytopenia

Step-1 IDENTIFY INPUT AND OUTPUT VARIABLES

Identify relevant input and output variables and their value ranges; here we identify four input variables [WC,HE,HG,PL] and three output variables [infection fight, Anemia,Thrombocytopenia].

Input variables and value ranges:

WC => [0,1600]HE => [30,60]

HG =>[5,18]BP =>[50,450]

Output variables and value ranges: Infection Fight=>[0,120] Anemia =>[0,120] Thrombocytopenia=>[0,120]

Input and output variables are identified and corresponding meaningful linguistic states are selected by expressing with the appropriate fuzzy logic. Following seven linguistic states are selected for each of the variables. VL =very low L=low BM=below medium M=medium AM=above medium H=high VH=very high

Step-2 "UNCERTAINTY IN THE ASSOCIATED MEASUREMENT IS INTRODUCED BY THE FUZZIFICATION FUNCTION"

Input Variables I ={WC,HE,HG,BP}Fuzzification Function fi applied to variable i.

fi: $[WCi_{min}, WCi_{max}]$-> R fi:$[HEi_{min}, HEi_{max}]$ -> R fi:$[HGi_{min}, HGi_{max}]$ -> R fi:$[BPi_{min}, BPi_{max}]$ -> R

Where R denotes the set of all fuzzy numbers and $fi(x_0)$ is a fuzzy number chosen by fi as fuzzy approximation of the measurement $i = x_0$

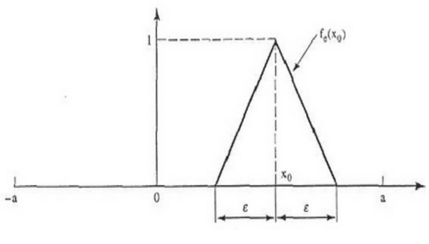

Fig 3.1: Fuzzification for variable i.

Following MF's used to represent the fuzzy numbers $fi(x_0)$

Step-3 GENERATE RULES

In this step fuzzy inference rules generated; relevant inference rules can be determined by experience human operators well we use IF ELSE conditions for fuzzy inference rules, as we have four input variables so total number of possible non conflicting fuzzy inference rules is 4^2 = 16. Rules conveniently be represented in IF-

ELSE Form:

1. IF (white-cell is very low) ^ (Hematocrit is very low) ^ (Hemoglobin is low) ^ (blood-platelets is very) THEN (Infection-Fight is very low)(Anemia is very high)(Thrombocytopenia is very high)
2. IF (white-cell is very low) ^ (Hematocrit is very low) ^ (Hemoglobin is low) ^ (blood-platelets is low) THEN (Infection-Fight is very low)(Anemia is very high)(Thrombocytopenia is high)
3. IF (white-cell is very low) ^ (Hematocrit is very low) ^ (Hemoglobin is very low) ^ (blood-platelets is very low) THEN (Infection-Fight is very low)(Anemia is very high)(Thrombocytopenia is very high)
4. IF (white-cell is very low) ^ (Hematocrit is very low) ^ (Hemoglobin is very low) ^ (blood-platelets is low) THEN (Infection-Fight is very low)(Anemia is very high)(Thrombocytopenia is high)
5. IF (white-cell is very low) ^ (Hematocrit is low) ^ (Hemoglobin is low) ^ (blood-platelets is very low) THEN (Infection-Fight is very low)(Anemia is high)(Thrombocytopenia is very high)
6. IF (white-cell is very low) ^ (Hematocrit is low) ^ (Hemoglobin is low) ^ (blood-platelets is low) THEN (Infection-Fight is very low)(Anemia is high)(Thrombocytopenia is high)
7. IF (white-cell is low) ^ (Hematocrit is very low) ^ (Hemoglobin is very low) ^ (blood-platelets is very low) THEN (Infection-Fight is low)(Anemia is very high)(Thrombocytopenia is very high)
8. IF (white-cell is low) ^ (Hematocrit is very low) ^ (Hemoglobin is very low) ^ (blood-platelets is low) THEN (Infection-Fight is low)(Anemia is very high)(Thrombocytopenia is high)
9. IF (white-cell is low) ^ (Hematocrit is very low) ^ (Hemoglobin is low) ^ (blood-platelets is very low) THEN (Infection-Fight is low)(Anemia is very high)(Thrombocytopenia is very high)
10. IF (white-cell is low) ^ (Hematocrit is very low) ^ (Hemoglobin is low) ^ (blood-platelets is low) THEN (Infection-Fight is low)(Anemia is very high)(Thrombocytopenia is high)
11. IF (white-cell is low) ^ (Hematocrit is low) ^ (Hemoglobin is low) ^ (blood-platelets is very low) THEN (Infection-Fight is low)(Anemia is high)(Thrombocytopenia is very high)

IF (white-cell is low) ^ (Hematocrit is low) ^ (Hemoglobin is low) ^ (blood-platelets is low) THEN (Infection-Fight is low)(Anemia is high)(Thrombocytopenia is high)

Step-4 INFERENCE ENGINE

Input of the controller should be combined with fuzzy information rules in such a ways that it must be conclusive towards the output variables. Inference engine is used for this purpose.

Step-5 DEFUZZIFICATION

Defuzzification is used to convert the output of the inference engine from fuzzy set in a single real number.

Table 3.2:MF's of white cells, red cells[Hematocrit], red cells[Hemoglobin] and Blood platelets input variables for diagnosis blood of liver disease using fuzzy logic

Membership Function-MF	[Leukocytes]	[Hematocrit]	[Hemoglobin]	Blood Platelets
Very Low	0-4000	30-35	5-8	50-150
Low	0-8000	30-40	5-11	50-250
Below Medium	-	35-45	8-13	-
Medium	4000-12000	40-50	11-16	150-350
Above Medium	-	45-55	13-18	250-450
High	8000-16000	50-60	16-18	350-450
Very High	12000-16000	55-60	-	-

Above table shows the value ranges of input variables against the membership functions for blood diagnosis of liver disease fuzzy design model. Each input variable have different number of membership functions. For Leukocytes input variable we define five membership functions; Hematocrit input variable have seven membership functions; Hemoglobin input variable have six MF's while Blood Platelets input variable have five membership functions; so we have seven distinct linguistic states against four input variables. Linguistic states are Very Low, Low, Below Medium, Medium, Above Medium, High and Very High.

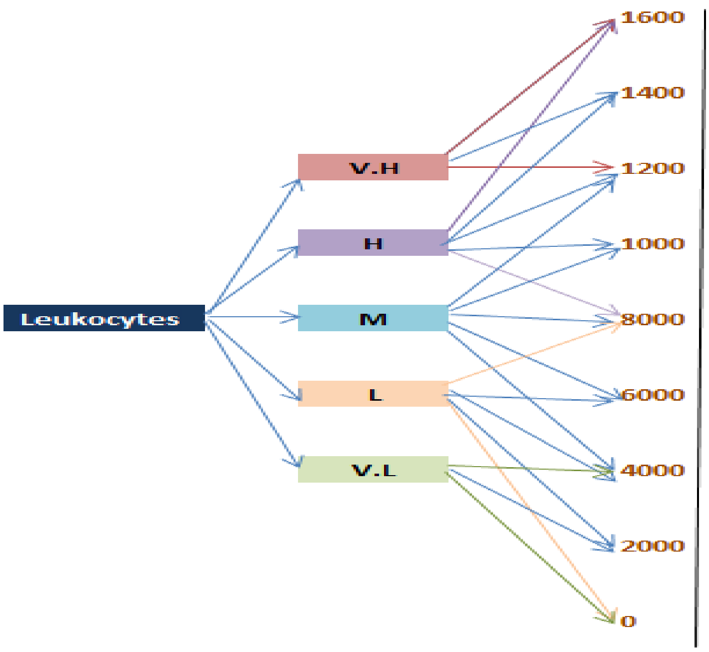

Fig 3.2: figure shows the linguistic state and value ranges for input variable 'LEUKOCYTES'

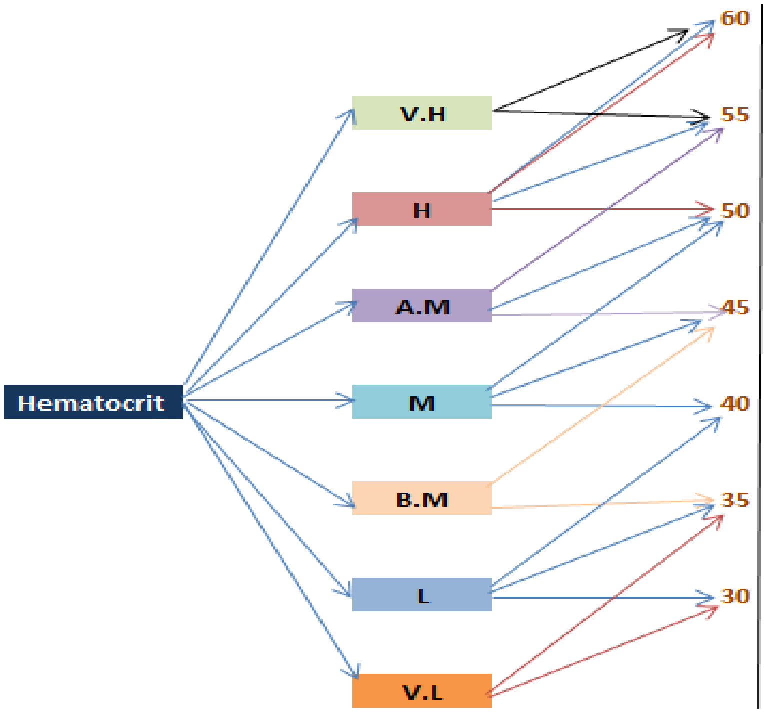

Fig 3.3: figure shows the linguistic state and value ranges for input variable 'HEMATOCRIT'

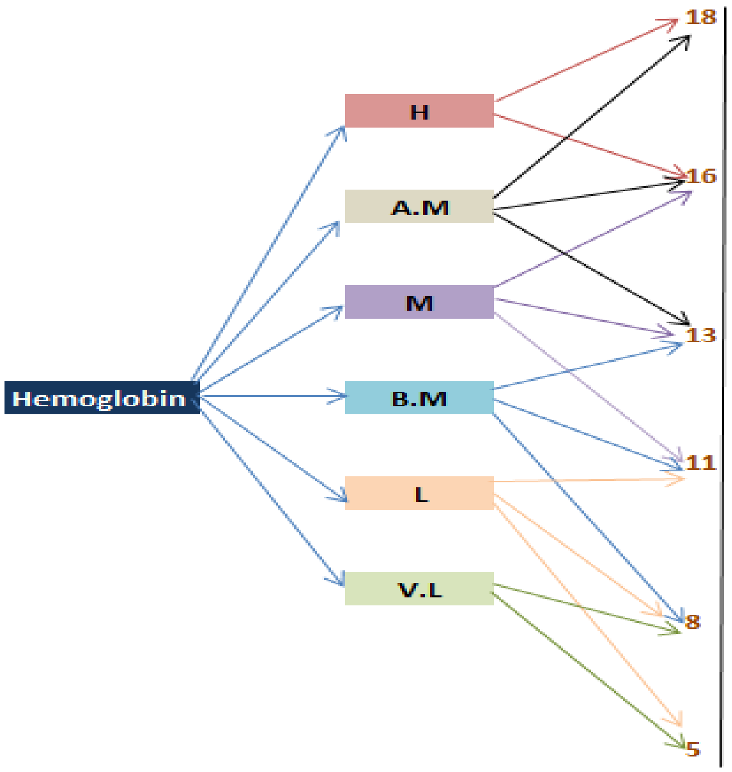

Fig 3.4:figure shows the linguistic state and value ranges for input variable 'HEMOGLOBIN'

Fig 3.1, Fig 3.2, Fig 3.3 and Fig 3.4 shows the membership function graph for each fuzzy input.

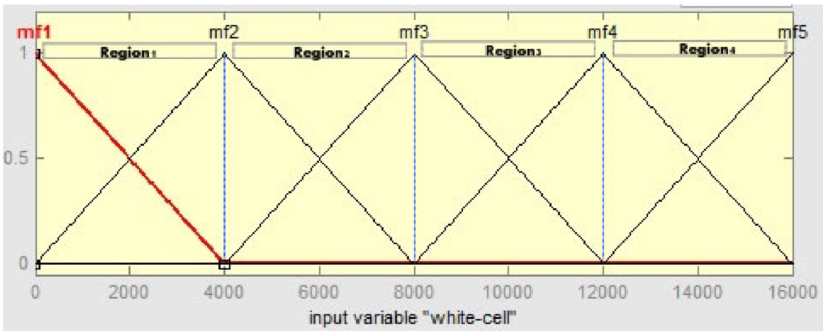

Fig 3.5:Graph of MFs for input fuzzy variable – white cells[leukocytes] for diagnosis blood for liver disease using fuzzy logic

The horizontal points of figure 3.1 are showing the value ranges of input variables leukocytes. While degree of membership shown vertically in the above figure. As we have five MF's of input variable leukocytes so total number of region can be calculated by Rg= Total MF-1 as Total MF=5 so 5-1=4Where Rg = Regions and Total MF=Total Membership functions.

The five membership functions, which are f1 [1], f1 [2],f1 [3],f1 [4] and f1 [5], can be used for the different ranges of the input fuzzy variables "White Cells[Leukocytes]" ashighlighted in Fig.3.6.

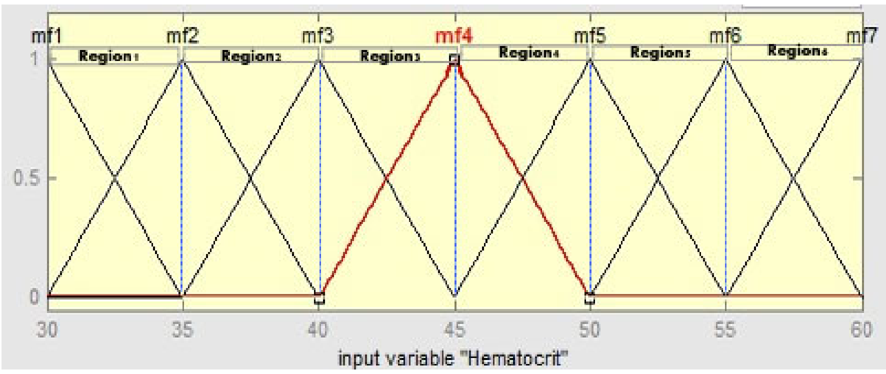

Fig 3.6: Graph of MFs for input fuzzy variable-red cells [Hematocrit] for diagnosis blood for liver disease using fuzzy logic

The horizontal points of figure 3.7 are showing the value ranges of input variables Hematocrit. While degree of membership shown vertically in the above figure. As we have seven MF's of input variable Hematocrit so total number of region can be calculated by Rg= Total MF-1 as Total MF=7 so 7-1=6

Where Rg = Regions and Total MF=Total Membership functions.

The seven membership functions, which are f2 [1], f2 [2],f2 [3], f2 [4], f2 [5], f2 [6] and f2 [7], can be used to describe the various ranges of input fuzzy variable “Red cells [Hematocrit]” as shown in Fig.3.7.

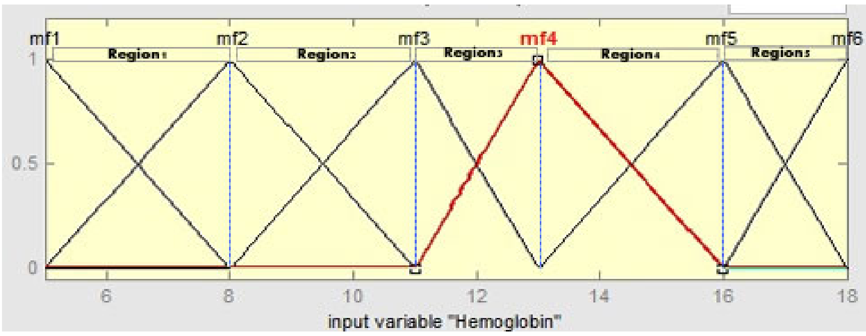

Fig 3.7: Graph of MFs for input fuzzy variable- red cells[Hemoglobin] for diagnosis blood for liver disease using fuzzy logic.

Horizontal points of figure 3.3 are showing the value ranges of input variables of Hemoglobin. While degree of membership shown vertically in the above figure. As we have seven MF’s of input variable Hemoglobin so total number of region can be calculated by Rg= Total MF-1 as Total MF=6 so 6-1=5

Where Rg = Regions and Total MF=Total Membership functions.

The sixmembership functions, f3 [1], f3 [2],f3 [3], f3 [4] , f3 [5] and f3 [6], which can be used to show the various ranges of input fuzzy variable “Red cells[Hemoglobin]” asshown in Fig.3.8.

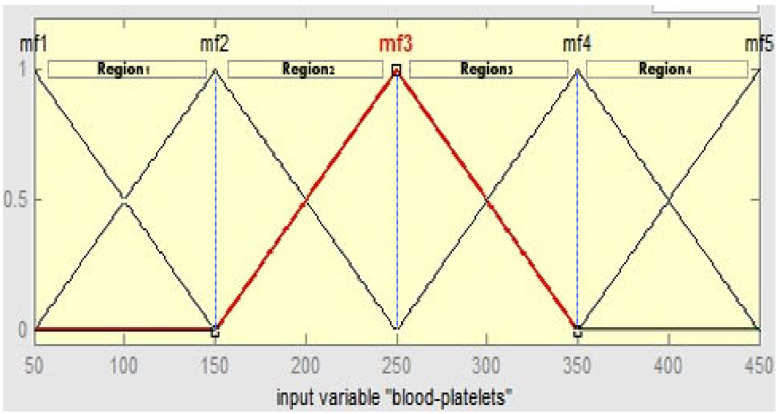

Fig 3.8: Graph of MFs for input fuzzy variable-blood platelets for diagnosis blood for liver disease using fuzzy logic

Horizontal points of figure 3.4 are showing the value ranges of input variables Blood Platelets. While degree of membership shown vertically in the above figure. As we have seven MF’s of input variable Blood Platelets so total number of region can be calculated by Rg= Total MF-1 as Total MF=5 so 5-1=4, Where Rg = Regions and Total MF=Total Membership functions.

Table 3.3:OutputMF'sfordiagnosis blood for liver disease using fuzzy logic

Membership Function	**Range**	**Infection-Fight**	**Anemia**	**Thrombocytopenia**
Very Low	0-30	0-30	0-30	0-30
Low	0-60	0-60	0-60	0-60
Medium	30-90	30-90	30-90	30-90
High	60-120	60-120	60-120	60-120
Very High	90-120	90-120	90-120	90-120

Shape ofthe graph for each output variable Infection-Fight, Anemia and Thrombocytopenia shown in Fig.3.5, Fig 3.6 and Fig 3.7

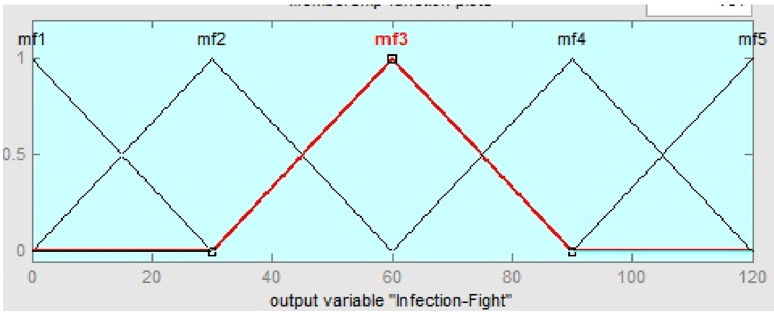

Fig 3.9: Graph of output MF- Infection-Fight for diagnosis blood for liver disease using fuzzy logic

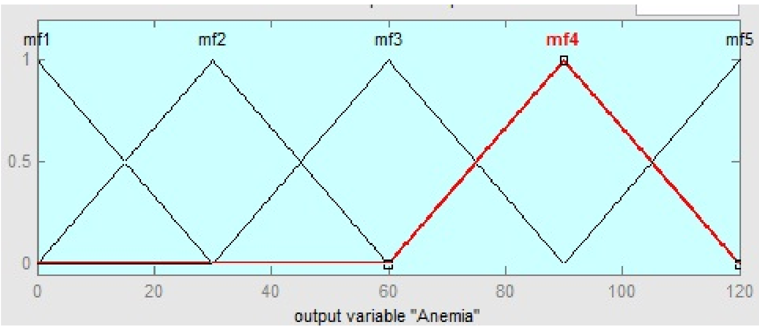

Fig 3.10: Graph of output MF- Anemia for diagnosis blood for liver disease using fuzzy logic

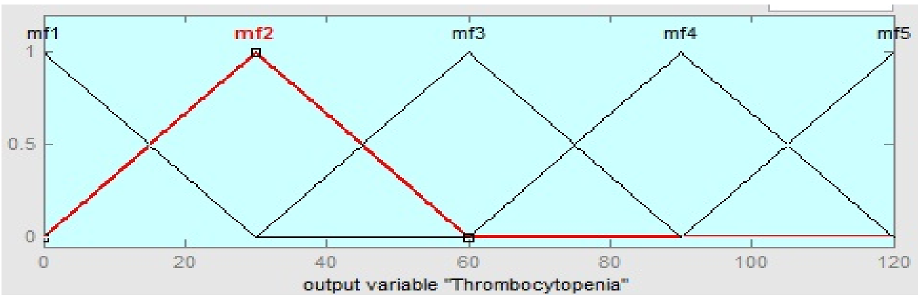

Fig 3.11: Graph of output MF- Thrombocytopenia for diagnosis blood for liver disease using fuzzy logic

3.2.2 Fuzzification

There are four variables in the proposed blood diagnosis for liver disease control system. These may have same values and share each of their values. The linguistic values “f1, f2”, “f3, f4”, “f5, f6” and “f7, f8” are for fuzzy variables “White Cells”, “Red blood cells [Hematocrit]”, “Red blood cells [Hemoglobin]”, and “Blood Platelets” respectively. The mapping values are the linguistic values gain through the membership function.

Table 3.4: Fuzzifiers outputs linguistic values in all regions for Liver disease blood diagnosis control system.

Input Variables	Linguistic Fuzzier Outputs	Region1	Region2	Region3	Region4
White Cells [Leukocytes]	F1	F1[1]	F1[2]	F1[3]	F1[4]
	F2	F1[2]	F1[3]	F1[4]	F1[5]
Red Cells [Hematocrit]	F3	F2[1]	F2[2]	F2[3]	F2[4]
	F4	F2[2]	F2[3]	F2[4]	F2[5]
Red Cells [Hemoglobin]	F5	F3[1]	F3[2]	F3[3]	F3[4]
	F6	F3[2]	F3[3]	F3[4]	F3[5]
Blood Platelets	F7	F4[1]	F4[2]	F4[3]	F4[4]
	F8	F4[2]	F4[3]	F4[4]	F4[5]

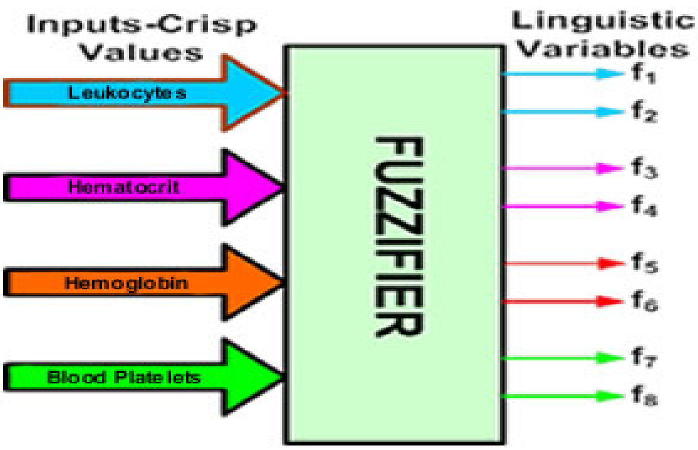

Fig 3.12:Fuzzifier showing 4- inputs- crisp values and 8-outputs- linguistic variables for diagnosis blood for liver disease using fuzzy logic

These variables are independent from one another. One may need following 12 rules to set the values in any of the region as each input variables has its own worth on the output.

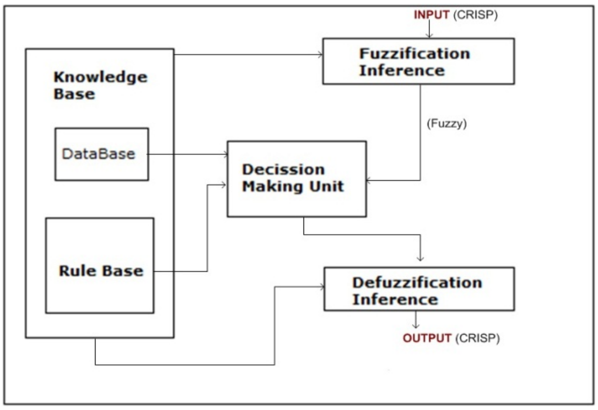

Fig 3.13: diagnosis control system

3.2.3 Inference Engine (IE)

There are 12 AND (not logical ANDs) operators in the Inference Engine (IE). IE accepts 10 values as an input and by using min-max composition it produces one value R as an output. Min-max composition is applied on the four inputs [Leukocytes,Hematocrit ,Hemoglobin and Blood Platelets].

Table 3.4: Linguistic Fuzzier Outputs against Input Variables and Fuzzy Set Calculations for Region1

Input Variables	**Linguistic Fuzzier Outputs**	**Fuzzy Set Calculationsfor Region1**
White Cells [Leukocytes]	F1	F1[1] = 0.3
	F2	F1[2] = 0.65
Red Cells [Hematocrit]	F3	F2[1] = 0.575
	F4	F2[2] = 0.4
Red Cells [Hemoglobin]	F5	F3[1] = 0.45
	F6	F3[2] = 0.55
Blood Platelets	F7	F4[1] = 0.275
	F8	F4[2] = 0.75

Table 3.5: Fuzzy Set Calculated values against Input Variables for Region1

Serial	Input Variables	Values	Region Selected
1.	White Cells [Leukocytes]	1333	0 **< 1333**< 4000 **Region1**
2.	Red Cells [Hematocrit]	33	30 <**33**< 35 **Region1**
3.	Red Cells [Hemoglobin]	6.3	0 <**6.3**< 8 **Region1**
4.	Blood Platelets	65	50 <**65**< 150 **Region1**

Fuzzy Sets Calculations

R1= f1 ^ f3 ^ f6 ^ f7 = 0.3 ^ 0.575 ^ 0.55 ^ **0.275** = **0.275**

R2= f1 ^ f3 ^ f6 ^ f8 = **0.3** ^ 0.575 ^ 0.55 ^ 0.75 = **0.3**

R3= f1 ^ f3 ^ f5 ^ f7 = 0.3 ^ 0.575 ^ 0.45 ^ **0.275** **=** **0.275**

R4= f1 ^ f3 ^ f5 ^ f8 = **0.3** ^ 0.575 ^ 0.45 ^ 0.75 = **0.3**

R5= f1 ^ f4 ^ f6 ^ f7 = 0.3 ^ 0.4 ^ 0.55 ^ **0.275** **=** **0.275**

R6= f1 ^ f4 ^ f6 ^ f8 = **0.3** ^ 0.4 ^ 0.55 ^ 0.75 = **0.3**

R7= f2 ^ f4 ^ f6 ^ f7 = 0.65 ^ 0.4 ^ 0.55 ^ **0.275** = **0.275**

R8= f2 ^ f4 ^ f6 ^ f8 = 0.65 ^ **0.4** ^ 0.55 ^ 0.75 = **0.4**

R9= f2 ^ f3 ^ f5 ^ f7 = 0.65 ^ 0.575 ^ 0.45 ^ **0.275** **=** **0.275**

R10= f2 ^ f3 ^ f5 ^ f8 = 0.65 ^ 0.575 ^ **0.45** ^ 0.75 = **0.45**

R11= f2 ^ f3 ^ f6 ^ f7 = 0.65 ^ 0.575 ^ 0.55 ^ **0.275** **=** **0.275**

R12= f2 ^ f3 ^ f6 ^ f8 = 0.65 ^ 0.575 ^ **0.55** ^ 0.75 = **0.55**

∑ R = R1+R2+ R3 + R4 + R5 + R6 + R7 + R8 + R9 + R10 + R11 + R12

=**0.275+ 0.3 + 0.275+ 0.3 + 0.275+ 0.3 + 0.275+ 0.4 + 0.275+ 0.45 + 0.275+ 0.55**

∑ **R = 3.95**

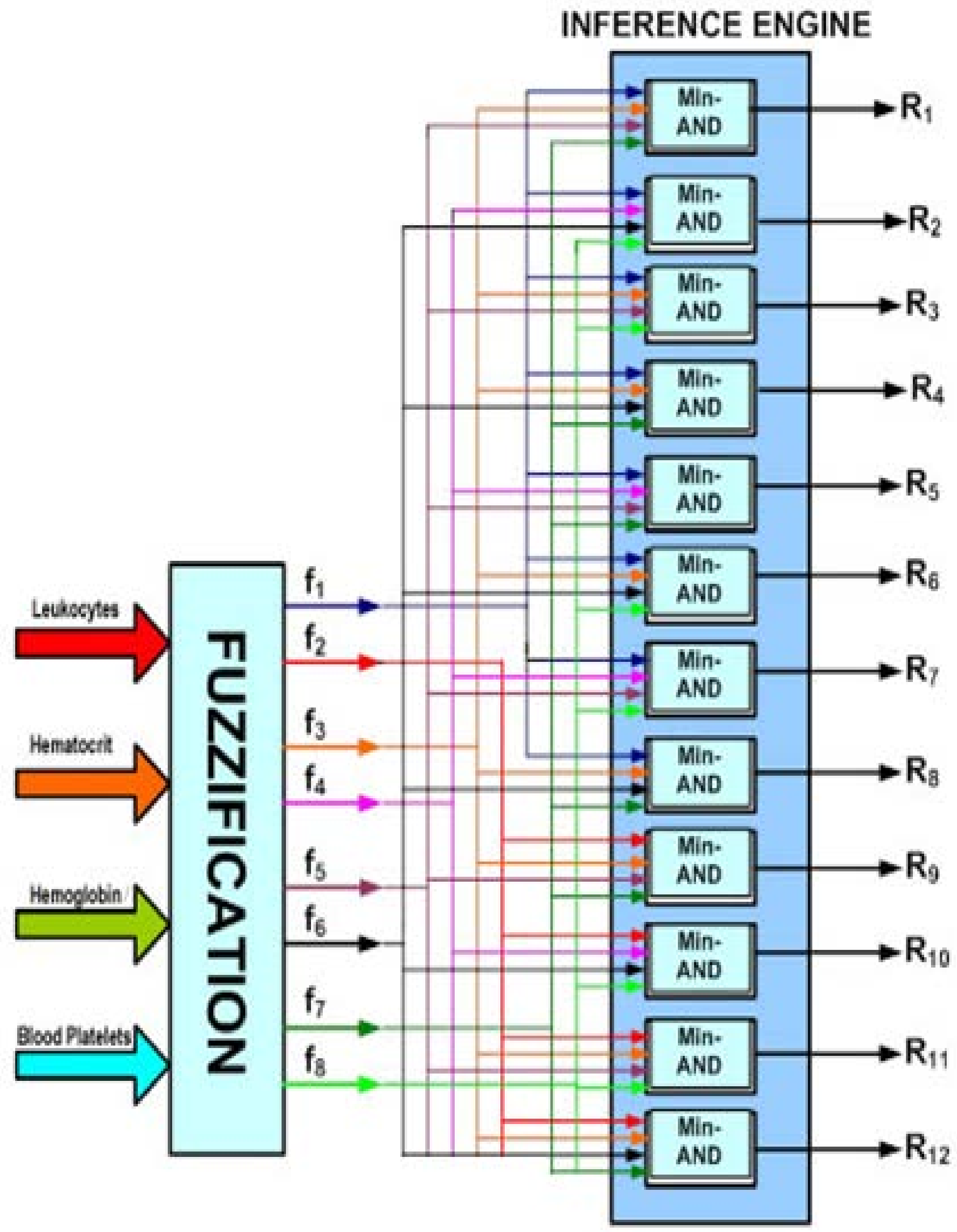

Fig 3.14:Block diagram of inference process for diagnosis blood for liver disease control systems

Four input crisp values entered in fuzzification and it generate eight linguistic variables; MIN-AND operation implemented by inference engine on each linguistic variable according to rule defined in the system.

3.2.4 Rule Selector

Four crisp values of the White cells, Hematocrit, Hemoglobin and Blood Platelets are selected by the Rule Selector of the proposed system. On the basis of the selected rules the rule selector gives the singleton values. From S1 to S12 rules have been selected and shown in the following table.

Table 3.6: Rules applied on Liver disease blood diagnosis control design model

Rule No.	*White cells*	*Hematocrit*	*Hemoglobin*	*Blood Platelets*	Ability to Fight	Anemia	Thrombocytopenia	Single-ton Value
1	Very Low	Very Low	Low	Very Low	Very Low	Very High	Very High	S1
2	Very Low	Very Low	Low	LOW	Very Low	Very High	High	S2
3	Very Low	Very Low	Very Low	Very Low	Very Low	Very High	Very High	S3
4	Very Low	Very Low	Very Low	LOW	Very Low	Very High	High	S4
5	Very Low	Low	Low	Very Low	Very Low	High	Very High	S5
6	Very Low	Low	Low	Low	Very Low	High	High	S6
7	Low	Very Low	Very Low	Very Low	Low	Very High	Very High	S7
8	Low	Very Low	Very Low	Low	Low	Very High	High	S8
9	Low	Very Low	Low	Very Low	Low	Very High	Very High	S9
10	Low	Very Low	Low	Low	Low	Very High	High	S10
11	Low	Low	Low	Very Low	Low	High	Very High	S11
12	Low	Low	Low	Low	Low	High	High	S12

Table 3.7:Illustration of applied rules with respect to MF's on diagnosis blood for liver disease design model

Rule No.	*White cells*	*Hematocrit*	*Hemoglobin*	*Blood Platelets*	Ability to Fight	Anemia	Thrombocytopenia	Single-ton Value
1.	MF1	MF1	MF2	MF1	MF1	MF5	MF5	**S1**
2.	MF1	MF1	MF2	MF2	MF1	MF5	MF4	**S2**

3.	MF1	MF1	MF1	MF1	MF1	MF5	MF5	**S3**
4.	MF1	MF1	MF1	MF2	MF1	MF5	MF4	**S4**
5.	MF1	MF2	MF2	MF1	MF1	MF4	MF5	**S5**
6.	MF1	MF2	MF2	MF2	MF1	MF4	MF4	**S6**
7.	MF2	MF1	MF1	MF1	MF2	MF5	MF5	**S7**
8.	MF2	MF1	MF1	MF2	MF2	MF5	MF4	**S8**
9.	MF2	MF1	MF2	MF1	MF2	MF5	MF5	**S9**
10.	MF2	MF1	MF2	MF2	MF2	MF5	MF4	**S10**
11.	MF2	MF2	MF2	MF1	MF2	MF4	MF5	**S11**
12.	MF2	MF2	MF2	MF2	MF2	MF4	MF4	**S12**

Table 3.8: Illustration of applied rules with respect to membership range values on diagnosis blood for liver disease design model

Rule No.	***White cells***	***Hematocrit***	***Hemoglobin***	***Blood Platelets***	**Ability to Fight**	**Anemia**	**Thrombocytopenia**	**Single-ton Value**
1.	0 - 4000	30 - 35	5 – 11	50 – 150	0 – 30	90 – 120	90 - 120	**S1**
2.	0 - 4000	30 - 35	5 – 11	50 – 250	0 – 30	90 – 120	60 - 120	**S2**
3.	0 - 4000	30 - 35	5 – 8	50 – 150	0 – 30	90 – 120	90 - 120	**S3**
4.	0 - 4000	30 - 35	5 – 8	50 – 250	0 – 30	90 – 120	60 - 120	**S4**
5.	0 - 4000	30 - 40	5 – 11	50 – 150	0 – 30	60 – 120	90 - 120	**S5**
6.	0 - 4000	30 - 40	5 – 11	50 – 250	0 – 30	60 – 120	60 - 120	**S6**
7.	0 - 8000	30 - 35	5 – 8	50 – 150	0 – 60	90 – 120	90 - 120	**S7**
8.	0 - 8000	30 - 35	5 – 8	50 – 250	0 – 60	90 – 120	60 - 120	**S8**
9.	0 - 8000	30 - 35	5 – 11	50 – 150	0 – 60	90 – 120	90 - 120	**S9**
10.	0 - 8000	30 - 35	5 – 11	50 – 250	0 – 60	90 – 120	60 - 120	**S10**
11.	0 - 8000	30 - 40	5 – 11	50 – 150	0 – 60	60 – 120	90 - 120	**S11**
12.	0 - 8000	30 - 40	5 – 11	50 – 250	0 – 60	60 – 120	60 - 120	**S12**

3.2.5 Rules

1. If (white-cell is mf1) and (Hematocrit is mf1) and (Hemoglobin is mf2) and (blood-platelets is mf1) then (Infection-Fight is mf1)(Anemia is mf5)(Thrombocytopenia is mf5)
2. If (white-cell is mf1) and (Hematocrit is mf1) and (Hemoglobin is mf2) and (blood-platelets is mf2) then (Infection-Fight is mf1)(Anemia is mf5)(Thrombocytopenia is mf4)
3. If (white-cell is mf1) and (Hematocrit is mf1) and (Hemoglobin is mf1) and (blood-platelets is mf1) then (Infection-Fight is mf1)(Anemia is mf5)(Thrombocytopenia is mf5)

4. If (white-cell is mf1) and (Hematocrit is mf1) and (Hemoglobin is mf1) and (blood-platelets is mf2) then (Infection-Fight is mf1)(Anemia is mf5)(Thrombocytopenia is mf4)
5. If (white-cell is mf1) and (Hematocrit is mf2) and (Hemoglobin is mf2) and (blood-platelets is mf1) then (Infection-Fight is mf1)(Anemia is mf4)(Thrombocytopenia is mf5)
6. If (white-cell is mf1) and (Hematocrit is mf2) and (Hemoglobin is mf2) and (blood-platelets is mf2) then (Infection-Fight is mf1)(Anemia is mf4)(Thrombocytopenia is mf4)
7. If (white-cell is mf2) and (Hematocrit is mf1) and (Hemoglobin is mf1) and (blood-platelets is mf1) then (Infection-Fight is mf2)(Anemia is mf5)(Thrombocytopenia is mf5)
8. If (white-cell is mf2) and (Hematocrit is mf1) and (Hemoglobin is mf1) and (blood-platelets is mf2) then (Infection-Fight is mf2)(Anemia is mf5)(Thrombocytopenia is mf4)
9. If (white-cell is mf2) and (Hematocrit is mf1) and (Hemoglobin is mf2) and (blood-platelets is mf1) then (Infection-Fight is mf2)(Anemia is mf5)(Thrombocytopenia is mf5)
10. If (white-cell is mf2) and (Hematocrit is mf1) and (Hemoglobin is mf2) and (blood-platelets is mf2) then (Infection-Fight is mf2)(Anemia is mf5)(Thrombocytopenia is mf4)
11. If (white-cell is mf2) and (Hematocrit is mf2) and (Hemoglobin is mf2) and (blood-platelets is mf1) then (Infection-Fight is mf2)(Anemia is mf4)(Thrombocytopenia is mf5)
12. If (white-cell is mf2) and (Hematocrit is mf2) and (Hemoglobin is mf2) and (blood-platelets is mf2) then (Infection-Fight is mf2)(Anemia is mf4)(Thrombocytopenia is mf4)

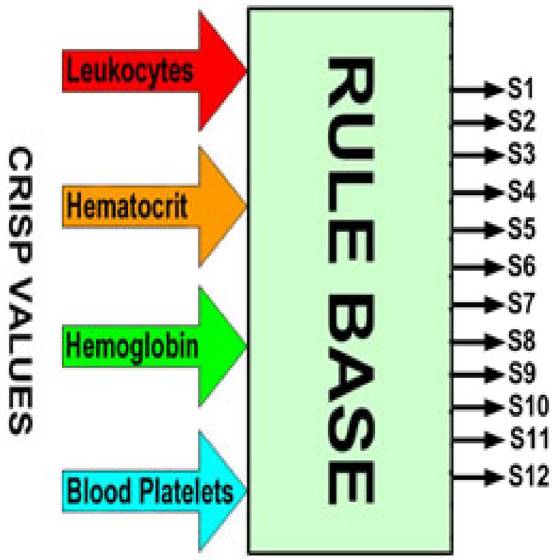

Fig 3.15:Block of Rule base for diagnosis blood for liver disease using fuzzy logic

3.2.6*Defuzzifier*

In the process of *defuzzification* under-generation outcomes of fuzzy set are converted to a single representative value [1]. The proposed system consists of three outputs for the function of human liver disease. These outputs describe the probability of the normal functionality and being in the disease. Defuzzification is also used to generate crisp values. In the proposed model the system is given 24 inputs. It is clear from the previous section that 12 rules were the outcome of the inference engine. The center of average (C.O.A) has been calculated mathematically by the following expression. $\sum$ Si × Ri / $\sum$ Ri where i = 1 to 12. The defuzzifier uses this method to calculate the crisp value output.

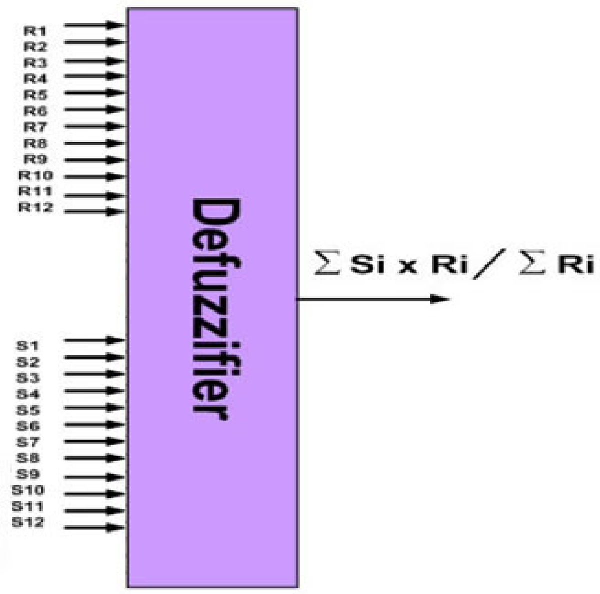

Fig 3.16:Defuzzifier block for medical diagnosis control system

Table 3.9: Illustration of applied rules on diagnosis blood for liver disease control design model

Rules	**S**	**Single-ton Value**			**Sri**		
		Ability to Fight	**Anemia**	**Thrombo - cytopenia**	**Ability to Fight SR**	**Anemia SR**	**Thrombocytopenia SR**
R1= 0.275	**S1**	0	1	1	0 * 0.275 =0	1*0.275 = 0.275	1*0.275 = 0.275
R2= 0.3	**S2**	0	1	0.75	0*0.3 = 0	1*0.3 = 0.3	0.75*0.3 = 0.225
R3= 0.275	**S3**	0	1	1	0*0.275= 0	1*0.275 =0.275	1*0.275 = 0.275
R4= 0.3	**S4**	0	1	0.75	0*0.3= 0	1*0.3 =0.3	0.75*0.3 = 0.225
R5= 0.275	**S5**	0	0.75	1	0*0.275= 0	0.75*0.275 = 0.20625	1*0.275 = 0.275
R6= 0.3	**S6**	0	0.75	0.75	0*0.3 =0	0.75*0.3 = 0.225	0.75*0.3 = 0.225
R7= 0.275	**S7**	0.25	0.75	1	0.25*0.275=0.06875	0.75*0.275 = 0.20625	1*0.275 = 0.275
R8= 0.4	**S8**	0.25	0.75	0.75	0.25*0.4=0.1	0.75*0.4 = 0.3	0.75*0.4 = 0.3
R9= 0.275	**S9**	0.25	1	1	0.25*0.275=0.06875	1*0.275 =0.275	1*0.275 = 0.275
R10= 0.45	**S10**	0.25	1	0.75	0.25*0.45=0.1125	1*0.45 =0.45	0.75*0.45 = 0.3375

R11= 0.275	**S11**	0.25	1	1	0.25*0.275=0.06875	1*0.275 = 0.275	1*0.275 = 0.275
R12 = 0.55	**S12**	0.25	1	0.75	0.25*0.55=0.1375	1*0.55 = 0.55	0.75*0.55 = 0.4125
∑ Single-ton Value * Rules					**∑ (SR) = 0.55625**	**∑ (SR) = 3.3375**	**∑ (SR) = 3.3125**
∑ (Single-ton Value * Rules) / ∑ R					**∑ (SR)/ ∑ R = 0.55625/3.95 = 0 .1408**	**∑ (SR)/ ∑ R = 3. 3375/3.95 = 0 .8449**	**∑ (SR)/ ∑ R = 3.3125 /3.95 = 0 8386**
(∑ (Single-ton Value * Rules) / ∑ R)*120					**0 .1408*120 = 16 89**	**0 .8449*120 = 101.39**	**0 8386*120= 100.63**

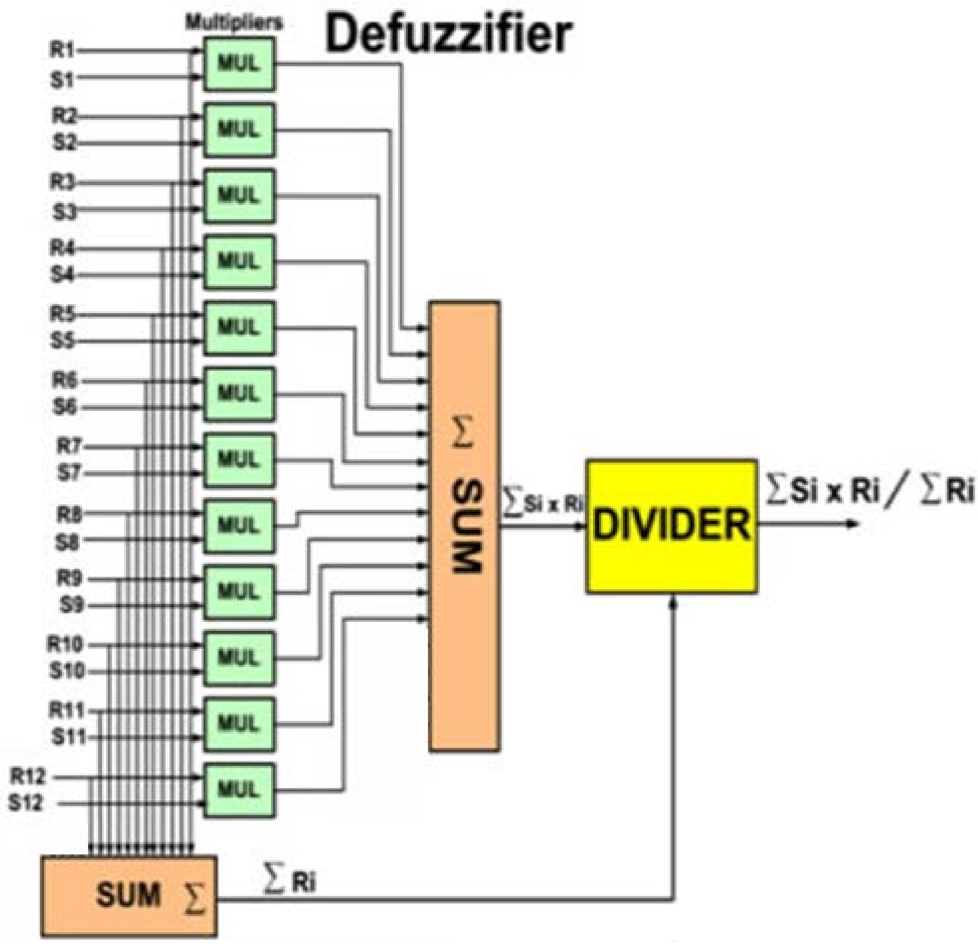

Fig 3.17: Defuzzifier design for diagnosis blood for liver disease using fuzzy logic.

Each multiplexer takes rule and single-ton value as an input (Single-ton Value * Rules) and sum the values ∑ Single-ton Value * Rules; divider divides the output of ∑ (Single-ton Value * Rules) to ∑ R.

4. Results and Discussions

4.1 Medical Diagnosis Control System

The medical diagnosis system is based on fuzzy logic model and it is simulated in Matlab. In this section, we describe the results and discuss it for further different values of the parameters used for the simulation.

4.1.1 Calculated arrangements and results

Four fuzzifiers and three defuzzifiers are used in this system. Calculation has been done for the input values, WHITE CELL=1333, RED BLOOD CELL (HEMOTOCRITE)=33%,HEMOGLOBIN=6.3 and BLOOD PLATELETS=65. Eight linguistics variables values are given by four fuzzifiers. Inference engine uses these values to apply eighteen inference rules.

Rule 1= f1 ^ f3 ^ f6 ^ f7 = 0.3 ^ 0.575 ^ 0.55 ^ **0.275** = **0.275**

Rule 2= f1 ^ f3 ^ f6 ^ f8 = **0.3** ^ 0.575 ^ 0.55 ^ 0.75 = **0.3**

Rule 3= f1 ^ f3 ^ f5 ^ f7 = 0.3 ^ 0.575 ^ 0.45 ^ **0.275** **=** **0.275**

Rule 4= f1 ^ f3 ^ f5 ^ f8 = **0.3** ^ 0.575 ^ 0.45 ^ 0.75 = **0.3**

Rule 5= f1 ^ f4 ^ f6 ^ f7 = 0.3 ^ 0.4 ^ 0.55 ^ **0.275** **=** **0.275**

Rule 6= f1 ^ f4 ^ f6 ^ f8 = **0.3** ^ 0.4 ^ 0.55 ^ 0.75 = **0.3**

Rule 7= f2 ^ f4 ^ f6 ^ f7 = 0.65 ^ 0.4 ^ 0.55 ^ **0.275** = **0.275**

Rule 8= f2 ^ f4 ^ f6 ^ f8 = 0.65 ^ **0.4** ^ 0.55 ^ 0.75 = **0.4**

Rule 9= f2 ^ f3 ^ f5 ^ f7 = 0.65 ^ 0.575 ^ 0.45 ^ **0.275** **=** **0.275**

Rule 10= f2 ^ f3 ^ f5 ^ f8 = 0.65 ^ 0.575 ^ **0.45** ^ 0.75 = **0.45**

Rule 11= f2 ^ f3 ^ f6 ^ f7 = 0.65 ^ 0.575 ^ 0.55 ^ **0.275** **=** **0.275**

Rule 12= f2 ^ f3 ^ f6 ^ f8 = 0.65 ^ 0.575 ^ **0.55** ^ 0.75 = **0.55**

∑ R = Rule1+Rule2+ Rule3 + Rule4 + Rule5 + Rule6 + Rule7 + Rule8 + Rule9 + Rule10 + Rule11 + Rule12 =**0.275+ 0.3 + 0.275+ 0.3 + 0.275+ 0.3 + 0.275+ 0.4 + 0.275+ 0.45 + 0.275+ 0.55 Sum of all Rule ∑ R = 3.95**
For four variables, the singleton values S1, S2, S3, S4, S5, S6, S7, S8 , S9, S10, S11 and S12 are found by the twelve rules using rule base. The three defuzzifiers are used to find crisp value outputs by accepting the values of Rule1, Rule2, Rule3, Rule4, Rule4, Rule5,............Rule12 and S1, S2, S3, S4, S5,..................S12. The Center

of average (C.O.A) method is used by each defuzzifier to estimate the crisp value output, having the mathematical expression. **Σ Si * Ri⁄ Σ Ri**, where i = 1 to 12.

4.1.2 Simulation Results

MATLAB-simulation is used by applying twelve rules.

Fig 4.1:MATLAB- simulation and rule viewer results for diagnosis blood for liver disease using fuzzy logic

Figure 4.2.1 shows the dependency of output variable Anemia on the input variable Hematocrit and Leukocytes(white cell); graph indicate that Anemia highly depends on Hematocrit while it has nearly no effect on white cell(leukocytes).

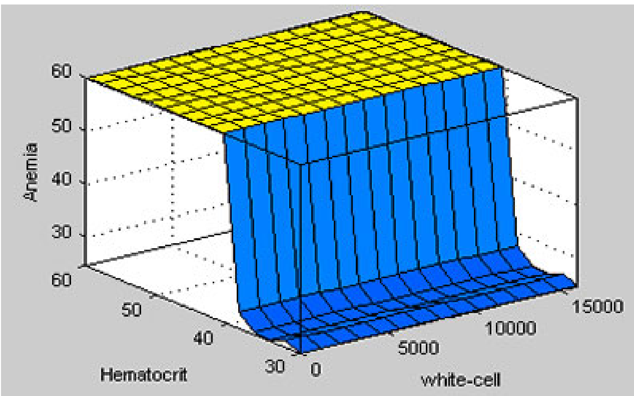

Fig 4.2.1: Graph between Anemia, Hematocrit and white-cell

Figure 4.2.2 shows the dependency of output variable Infection Fight on the input variable Hematocrit and Leukocytes (white cell); output variable infection fight highly depends on white cell (leukocytes) while Hematocrit has no effect on it.

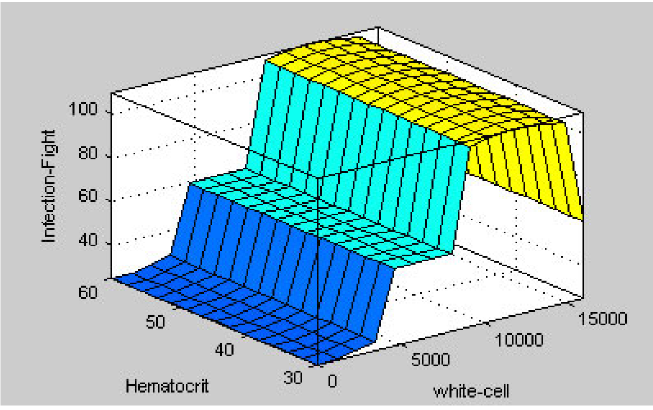

Fig 4.2.2: Graph between white-cell, Infection-Fight and Hematocrit

Figure 4.2.3 shows the dependency of output variable Anemia on the input variable Hemoglobin and input variable Hematocrit; graph clearly shows that Anemia highly depends on both Hemoglobin and Hematocrit.

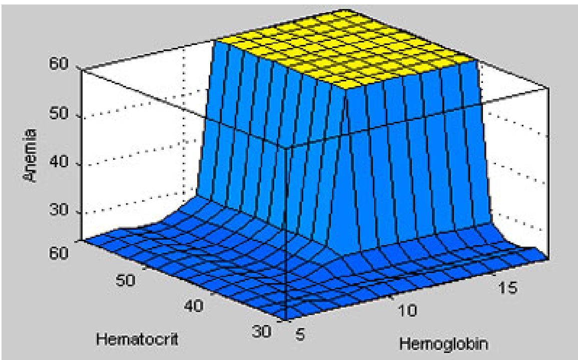

Fig 4.2.3: Graph between Hematocrit, Hemoglobin and Anemia

Figure 4.2.4 indicate the dependency of output variable Thrombocytopenia on the input variable Hemoglobin and Blood platelets, graphs shows that the Thrombocytopenia has nearly no effect on Hemoglobin but Blood Platelets has highly effect on Thrombocytopenia Output variables.

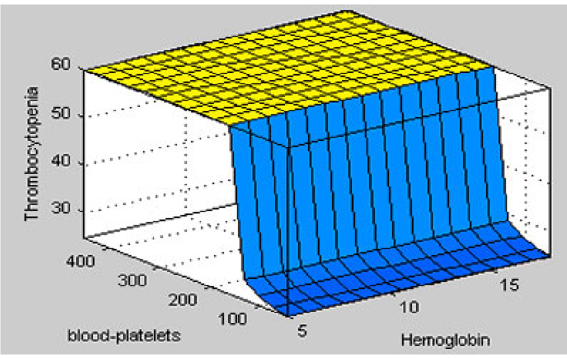

Fig 4.2.4: Graph between Thrombocytopenia, Hemoglobin and blood-platelets

Fig.4.2(1-4) MATLAB simulation graphs for liver disease blood diagnosis using fuzzy logic

4.1.3 Results Discussion

White Cells leukocytes, Red Cells Hematocrit, Hemoglobin and Blood Platelets effect; the normal (normality of human liver function), the anemia and thrombocytopenia, according to the design scheme of medical diagnosis control system.

4.1.4 Future Work

Any number of inputs can be added in order to extend the designed system; for chemistry panel four categories of input scan be added and for liver function test more nine categories can be added in order to get more deep and appropriate results. Fig.4.2 shows output variables all dependencies on input variables. Fig.4.2 (a) shows that the normal depends on the white cells normal. Fig.4.2(b) shows that the normal only depends on hematocrit. Simulated and calculated results comparison shown in table 4.1.

Table 4.1: Conclusion and future work of the diagnosis blood for liver disease using fuzzy logic

Results	**Infection-Fight**	**Anemia**	**Thrombocytopenia**
MATLAB Simulation	*17.2*	*100.6*	*98.9*
Calculated Values	**16.89**	**101.39**	**100.63**
Difference	*0.31*	*0.79*	*1.73*
% Error	**1.8%**	**0.7%**	**1.7%**

4.1.5 Conclusion

Both the design model and simulation result are same. The designed system can be extended for any number of inputs. We can define this system more than four inputs to get more efficient human diagnose results. The design work is being carried out to design state of the art fuzzy logic medical diagnosis control system in future using FPGAs.

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