DESIGN MODEL OF FUZZY LOGIC MEDICAL DIAGNOSIS CONTROL SYSTEM

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Abstract— **This research work addresses the medical diagnosis regarding the normality of a human function in human brain and the diagnosis of hemorrhage and brain tumor. It enhances the control strategies in the medical field to diagnose a disease. This system using fuzzy logic design: fuzzifier, inference engine, rule base, and defuzzification is capable to be used for medical diagnosis giving the entries of five inputs: Protein , Red blood cells , Lymphocytes , Neutrophils and Eosinophils, and taking three outputs: Normal, Hemorrhage and Brain Tumor. The medical diagnosis fuzzy rules are formulated and applied using MATLAB simulation for the system. The simulation results are found in agreement with the design based calculated results. This research work proposes to develop a control system to enhance the efficiency to diagnose a disease related to human brain.**

Keywords- Medical diagnosis, Fuzzy logic medical system and medical diagnosis fuzzy rules

I. INTRODUCTION

The nonlinear systems difficult to model mathematically are usually monitored by fuzzy logic. It is a system of logic and based on set theory and continuous variables. Fuzzy logic is a methodology for problem solving or in other words “problem solving control system methodology”. Its implementation can be performed in hardware or software or by combining both. Conclusions that are based on vague, imprecise, missing input information are simply provided by fuzzy logic FL.

An article by zadeh [1] describes that the application of fuzzy logic that have been applied to many areas or fields, for example fuzzy logic has played an important role in the field of medicine. Over the last 20 years applications of FL have become widely used. They are used in control, automobiles, household appliances and decision making systems. These applications also spread in medicine field.

Fuzzy logic uses different vocabulary in itself, i.e fuzzification, defuzzification, membership function, linguistic variables, domain, rules etc. In Boolean algebra or Boolean logic crisp sets are used, which has only two values 0 and 1, but in fuzzy logic sets have infinite logic values between 0 and 1, in Boolean logic completely inclusive, exclusive membership is used, but in FL completely inclusive, exclusive or between these two membership is used.

Fuzzy logic control systems are used to handle difficult processes on the bases of human knowledge. FLC systems and expert systems have the same ground, but expert system can not handle the difficult process where as the FLCS are used for the ambiguous process. The old control methods are mostly have physical model so

these are mostly time consuming and need a strong theoretical background and mostly have human operator to operate. But FLC controller uses linguistic rules that show the strategy of the user.

The basic advantage of this method that it does not requires the model [2]. Knowledge based systems in which fuzzy logic controllers are explained with the help of IF-THEN rules are based on professional's knowledge about system controllers, performance etc and established. Such kind of control system is fuzzy logic control systems. Designer's experience and information are the factors upon which the input-output intervals and membership functions depends. The reason for designing and application of FLCS is to handle the ambiguous and unclear and difficult processes which are not easily handled by old techniques of the control systems. Also the fuzzy expert system is a system in which fuzzy rules are used with MF to find the conclusion or result.

Predefined patterns and the behaviour of a process are mostly controlled by Diagnostic systems. The problems controlled by such systems involve suggestions for a certain treatment after identification. Diagnostic systems are in the form of an expert system based on rules. Sure patterns are explained by set of rules which is called as rule based expert system. Evaluation of rules is done after the collection of observed data. Identification of pattern and suggestion of problem linked with that pattern is given when the rules are logically satisfied. Implication of certain treatment is performed by each one of specific problem. Normally computation of human expert is performed by diagnostic system instead of its replacement. So the conclusive decision is finally made by human diagnostic expert to search the reason and give the prescription.

FL has been used in diagnostics for cancer and diabetes [3]. Turku University Hospital has made software known as DIAGAID that uses FL [4]. Results from the research studies in Finland [5, 6, 7] and data from international publications [8] used in this thesis.

Scott S. Lancaster et al. discussed the design of Fuzzy logic controller (FLC) for medical device based on software using fuzzy logic. FLC used for controlling the regulator to apply air pressure to the skin of human consisting of analogue-to-digital convertor for the collection of data, pneumatic valve and sensor to control air pressure [9]. Ch. Schuh et al. described how fuzzy logic used in medical human health care system and the medical data of patient [11].

M. Mahfouf , M.F.Abbod , D.A.Linkens et al. explained the use of fuzzy logic in the neuro medical field, fuzzy logic evaluation on the basis of facial expression and human behavior etc., surveyed different fuzzy techniques using the data analysis of medical science [16].

Yataka Hata , Syoji Kobashi and Hiroshi Nakajima et al. described the practical application of management system for human health and worked on the scheme to concentrate medical diagnosis and health management [13].

He Yue , Guo Yue and Guo Yi et al. described the immune system that protects the human body, on the basis of the immune algorithm using a flow chart and Fuzzy Cognitive Map (FCM) [12].

Christian J. Schuh et al. proposed a survey related to the fuzzy logic, fuzzy sets and relations and fuzzy control and their application in medical science and explained GlucoNotify patient glucose data setting, fuzzy automata concept for ARDS therapies [15].

Supriya Kumar De, Ranjit Biswas and Akhil Ranjan Roy et al. proposed to extend the research and using the idea of intuitionistic fuzzy set theory and introduced the case study of some patients, collected the data of their symtoms and used this data in IF theory and gave the result in tabular form [14].

This research work proposed a diagnosis of the haemorhage and brain tumor disease to show the probability of the disease. The simulation of fuzzy logic results shows the probability of the disease to occur and normal result probability. Hemorrhage and tumor occur by the abnormal increase or decrease of blood cells in the cerebrospinal fluid. The data range of the blood cells includes red blood cells, lymphocytes, protein, neutrophils, and eosinophils. These cells are used as input parameters for the fuzzy logic system. Cells make inputs which are to be fuzzified. On the basis of fuzzy rules fuzzified outputs are collected. The output describes which disease is probable and the chances of the normality by the change in the input parameters that are blood cells. The fuzzy surfaces are obtained and graphical relationship between the input parameters and output are shown.

The frame work of this paper consists of: An overview of fuzzy logic medical diagnosis control system is given in section II, section III describes design algorithm of fuzzy logic medical diagnosis control system,section IV includes the results and discussion, whereas conclusion and future work are given in section V.

II. OVER VIEW OF FUZZY LOGIC MEDICAL DIAGNOSIS CONTROL SYSTEM

This work proposes diagnostic system using fuzzy logic control system and its design and simulation. Predefined patterns and the behaviour of a process are mostly controlled by diagnostic systems. The problems controlled by such systems involve suggestions for a certain treatment after identification. Diagnostic systems are in the form of an expert system based on rules. Sure patterns are explained by set of rules which is called as rule based expert system. Evaluation of rules is done after the collection of observed data. Identification of pattern and suggestion of problem linked with that pattern is given when the rules are logically satisfied. Implication of certain treatment is performed by each one of specific problem. Normally computation of human expert is performed by diagnostic system instead of its replacement. So the conclusive decision is finally made by human diagnostic expert to search the reason and give the prescription. Fuzzy logic (FL) has been used in diagnostics for cancer and diabetes [3].

Turku University Hospital has made software known as DIAGAID that uses FL [4]. Results from the research studies in Finland [5, 6, 7] and data from international publications [8] are used. The various terms: Cerebrospinal fluid (CSF), Blood and types in CSF; Red blood cells, Lymphocytes, Neutrophils and Eosinophils, Protein used in this research are explained. CSF is a fluid present in nervous system (nervous blood) of the human body. The main function of cerebrospinal fluid is the brain and spinal cord fluid; influx of hormones etc. the puncture or abnormality of CSF include; spinal cord disorder, hemorrhage, tumors and many more. Red blood cells are the very numerous types in the blood. This type is used for the transport of CO_2 and O_2. The quantity of these cells in the blood is much less than RBS.

These are the type of white blood cells used in the defensive and immune system of the body. Lymphocytes are in the bone marrow. These are also white blood cells.

Eosinophils are the type of white blood cells and use in the immune system of the body. These are present in blood, bone marrow and in tissues. Protein enters the CSF through blood also protein transfer from brain to CSF.

III. DESIGN ALGORITHM OF FUZZY LOGIC MEDICAL DIAGNOSIS CONTROL SYSTEM

The work related to the proposed design model of fuzzy logic medical diagnosis control system for the diagnosis of human disease; hemorrhage and brain tumor is discussed. It also gives the probability of normality of human.

A. Design Algorithm

This system is designed for the five fuzzy input variables. Table 1 shows the membership functions of the five variables: proteins, red blood cells, lymphocytes, neutrophils and eosinophils. The ranges of inputs variables [20] are given in the table.

TABLE 1 MEMBERSHIP FUNCTIONS OF INPUT VARIABLES; PROTEIN, RED BLOOD CELL, LYMPHOCYTES, NEUTROPHILS, AND EOINOPHILS

Membership Function-MF	Protein in (mg/l)	Red blood cells in (E6/l)	Lymphocytes in (%)	Neutrophils in (%)	Eosinophils in (%)
Low	200-500	0-5	50-75	0-3	0-10
High	400-1150	3-50	60-97	3-60	0-18
Very High	700- >1200	25- >50	80-100	38- >72	13-25

Fig 1, Fig 2, Fig 3, Fig 4 and Fig 5 show the membership function plots for each fuzzy input. The three membership functions, f1 [1], f1 [2] and f1 [3] are used to show the various ranges of input fuzzy variable "Protein" in a plot consisting of two regions as shown in Fig. 1.

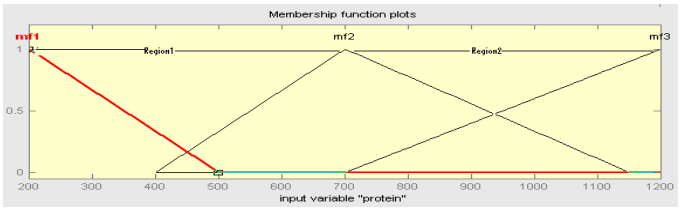

Figure 1 Plot of membership functions for input fuzzy variable – protein for fuzzy logic medical diagnosis control system

The three membership functions, f2 [1], f2 [2] and f2 [3] are used to show the various ranges of input fuzzy variable "Red blood cell" in a plot consisting of two regions as shown in Fig. 2

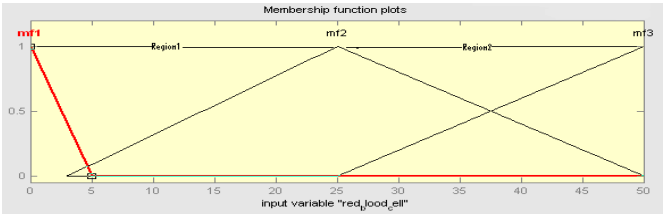

Figure 2 Plot of membership functions for input fuzzy variable-red blood cell for fuzzy logic medical diagnosis control system

The three membership functions, f3 [1], f3 [2] and f3 [3] are used to show the various ranges of input fuzzy variable "Lymphocytes" in a plot consisting of two regions as shown in Fig. 3.

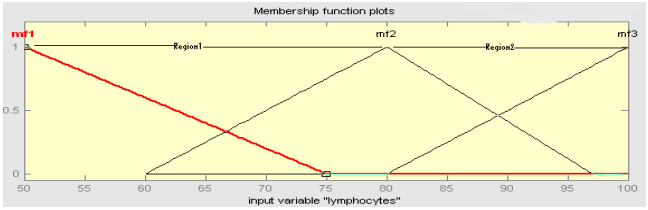

Figure 3 Plot of membership functions for input fuzzy variable- lymphocytes for fuzzy logic medical diagnosis control system

The three membership functions, f4 [1], f4 [2] and f4 [3] are used to show the various ranges of input fuzzy variable "Neutrophils" in a plot consisting of two regions as shown in Fig. 4.

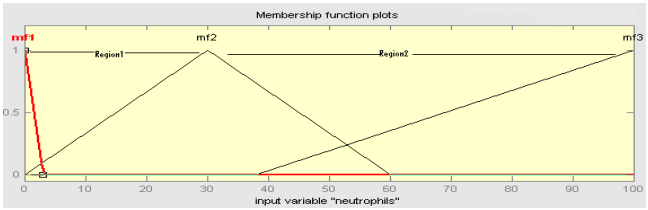

Figure 4 Plot of membership functions for input fuzzy variable-neutrophils for fuzzy logic medical diagnosis control system

The three membership functions, f5 [1], f5 [2] and f5 [3] are used to show the various ranges of input fuzzy variable "Eosinophils" in a plot consisting of two regions as shown in Fig. 5.

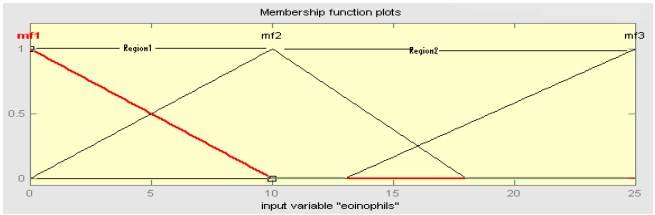

Figure 5 Plot of membership functions for input fuzzy variable-eoinophils for fuzzy logic medical diagnosis control system

There are three output variables. The plot of membership function for each variable consists of three functions. Each membership function's detail is shown in Table 2.

TABLE 2 OUTPUT MEMBERSHIP FUNCTIONS FUZZY LOGIC MEDICAL DIAGNOSIS CONTROL SYSTEM

Membership Function	Range	Normal	Hemorrhage	Brain Tumor	Singleton Value
Mf1	0-0.4	Normal	Not Probable	Not Probable	S1=0
Mf2	0.1-0.9	Not Normal	Uncertain	Uncertain	S2=0.005
Mf3	0.6-1	Uncertain	Probable	Probable	S3=0.01

Shape of the plot for each output variable, normal, hemorrhage and brain tumor are shown in Fig. 6, Fig 7 and Fig 8.

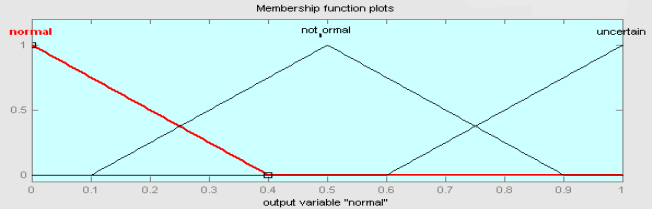

Figure 6 Plot of output membership function-normal for fuzzy logic medical diagnosis control system

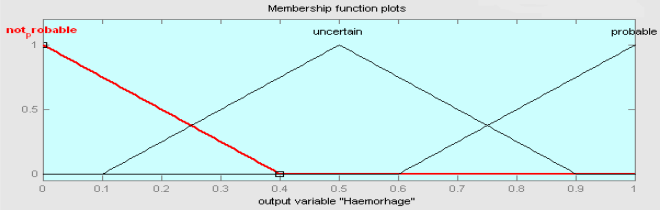

Figure 7 Plot of output membership function-hemorrhage for fuzzy logic medical diagnosis control system

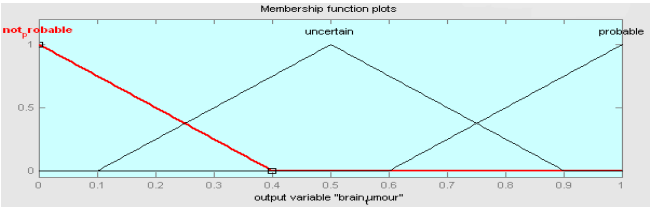

Figure 8 Plot of output membership function-brain tumor for fuzzy logic medical diagnosis control system

B. Fuzzification

The proposed fuzzy logic medical diagnosis control system consists of five input variables. Any one of the two regions may have values of each variable. Fuzzy variable "Protein" has the linguistic values f_1 and f_2, fuzzy variable "Red blood cells" has the linguistic values f_3 and f_4, "Lymphocytes" has f_5 and f_6, "Neutrophils" has f_7 and f_8, "Eosinophils" has f_9 and f_{10}. The mapping values of input variable through the membership function are the linguistic values. Fig 9 shows the ten linguistic values because we are using five variables. The mapping of input variables with the membership functions in two regions is listed in Table 3.

TABLE 3 LINGUISTIC VALUES OF FUZZIFIERS OUTPUTS IN ALL REGIONS FOR MEDICAL DIAGNOSIS CONTROL SYSTEM.

Input variables	Linguistic Fuzzifier outputs	Region 1	Region 2
Protein	f_1	$f_1[1]$	$f_1[2]$
	f_2	$f_1[2]$	$f_1[3]$
Red blood cells	f_3	$f_2[1]$	$f_2[2]$
	f_4	$f_2[2]$	$f_2[3]$
Lymphocytes	f_5	$f_3[1]$	$f_3[2]$
	f_6	$f_3[2]$	$f_3[3]$
Neutrophils	f_7	$f_4[1]$	$f_4[2]$
	f_8	$f_4[2]$	$f_4[3]$
Eosinophils	f_9	$f_5[1]$	$f_5[2]$
	f_{10}	$f_5[2]$	$f_5[3]$

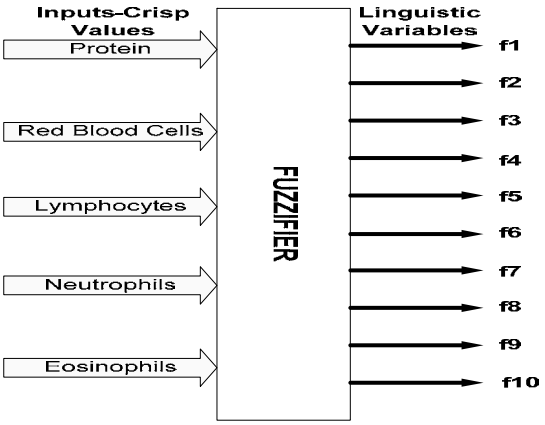

Figure 9 Fuzzifier showing 5- inputs- crisp values and 10-outputs- linguistic variables for fuzzy logic medical diagnosis control system

As all the variables are independent of each other, therefore all the variables may lie in any of the regions. Therefore 17 rules are required because input variables do not depend upon each other. Each input variable behaves an individual effect on output.

C. INFERENCE ENGINE (IE)

The IE consists of seventeen AND operator, in fact these operators select minimum input value for the output and also these are not the logical ANDs. This IE takes ten inputs from the fuzzifier to produce the output R value according to the min-max composition.

This method uses min-max operation between the five inputs.

R1= f1 ^ f3 ^ f5 ^ f7 ^ f9 = f1 [1] ^ f2 [1] ^ f3 [1] ^ f4 [1] ^ f5 [1]

R2= f2 ^ f4 ^ f6 ^ f8 ^ f10 = f1 [3] ^ f2 [3] ^ f3 [3] ^ f4 [3] ^ f5 [3]

R3= f1 = f1 [1]

R4= f3 = f2 [1]

R5= f5 = f3 [1]

R6= f7 = f4 [1]

R7= f9 = f5 [1]

R8= f2 = f1 [2]

R9= f4 = f2 [2]

R10= f6 = f3 [2]

R11= f8 = f4 [2]

R12= f10 = f5 [2]

R13= f2 = f1 [3]

R14= f4 = f2 [3]

R15= f6 = f3 [3]

R16= f8 = f4 [3]

R17= f10 = f5 [3]

The sign ^ between the membership function values is used for Min-ANDing process. In this process we get the minimum of the function values being ANDed. This interpretation is used in Mamdani-min process. Fig 10 shows the block diagram of inference process.

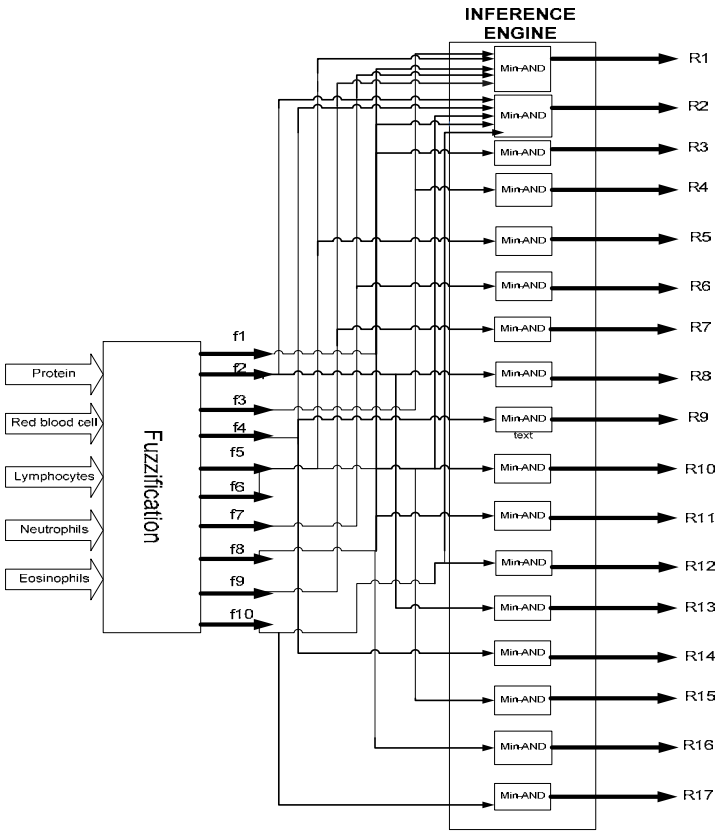

Figure 10 Block diagram of inference process for medical diagnosis control systems

D. RULE SELECTOR

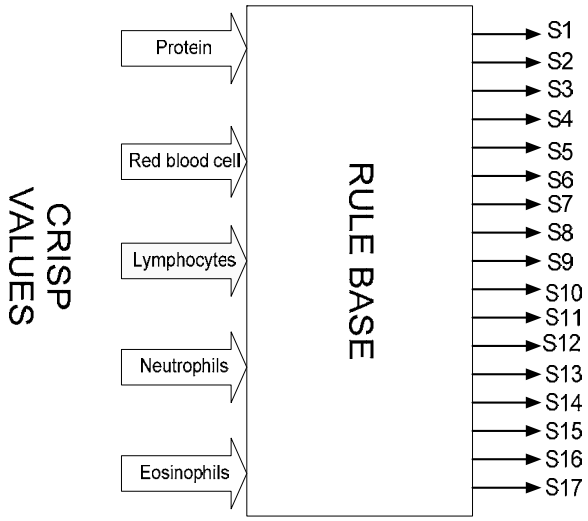

Figure 11 Block of Rule base for fuzzy logic medical diagnosis control system

The selector of rules for the proposed system gets five crisp values of protein, red blood cells, lymphocytes, neutrophils and eosinophils.

Rule selector gives singleton value of output function on the basis of rules. For five variables, we have seventeen rules to get the values of S1, S2, S3, S4, S5, S6, S7, S8, S9, S9, S10, S11, S12, S13, S14, S15, S16 and S17. Table 4 shows the list of rules.

TABLE 4 ILLUSTRATION OF APPLIED RULES ON MEDICAL DIAGNOSIS CONTROL DESIGN MODEL

Rule no.	Protein	Red blood cells	Lymphocytes	neutrophils	Eosinophils	Normal	Hemorrhage	Brain Tumor	Singleton value
1.	low	low	low	low	low	Probable	-	-	S1
2.	v.high	v.high	v.high	v.high	v.high	Not probable	-	-	S2
3.	low	-	-	-	-	probable	uncertain	uncertain	S3
4.	-	low	-	-	-	probable	Not probable	uncertain	S4
5.	-	-	low	-	-	probable	probable	probable	S5
6.	-	-	-	low	-	probable	Not probable	Not probable	S6
7.	-	-	-	-	low	probable	uncertain	probable	S7
8.	high	-	-	-	-	Not probable	probable	probable	S8
9.	-	high	-	-	-	Not probable	uncertain	probable	S9
10.	-	-	high	-	-	uncertain	Not probable	uncertain	S10
11.	-	-	-	high	-	Not probable	probable	probable	S11
12.	-	-	-	-	high	Not probable	Not probable	uncertain	S12
13.	v.high	-	-	-	-	Not probable	probable	probable	S13
14.	-	v.high	-	-	-	Not probable	probable	probable	S14
15.	-	-	v.high	-	-	Not probable	Not probable	Not probable	S15
16.	-	-	-	v.high	-	Not probable	probable	uncertain	S16
17.	-	-	-	-	v.high	Not probable	Not probable	Not probable	S17

Fig. 12 shows the arrangement of region detector and decoder for fuzzy control system and Fig. 13 shows the singleton values arrangement for Fuzzy logic medical diagnosis control system.

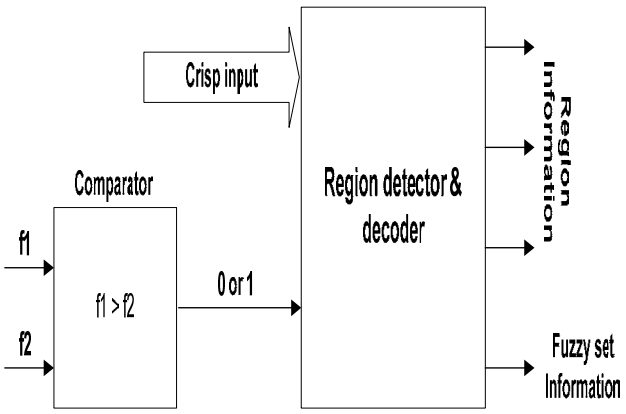

Figure 12 Arrangement of region detector and decoder for fuzzy control system

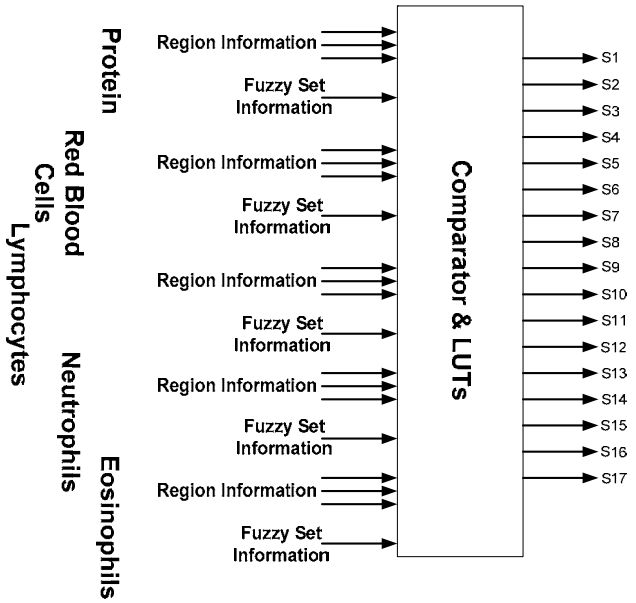

Figure 13 Singleton values arrangement for Fuzzy logic medical diagnosis control system

E. DEFUZZIFIER

This system has three outputs that describe the function of human, in fact explains the disease and normal function or we can say that it shows the probability of normal function and disease.

The crisp value output is given by the defuzzification process after estimating its input value. This system has 34 inputs that are given to the defuzzifier. From the output of inference engine we have seventeen values of R1, ….. , R17 and from the selector of rules we have seventeen values S1, …….., S17. In this system we have center of average (C.O.A) method which has the mathematical expression that is.

$\sum Si \times Ri / \sum Ri$ where i = 1 to 17.

The defuzzifier block is shown in Fig. 14 and Fig. 15 uses this method to calculate the crisp value output.

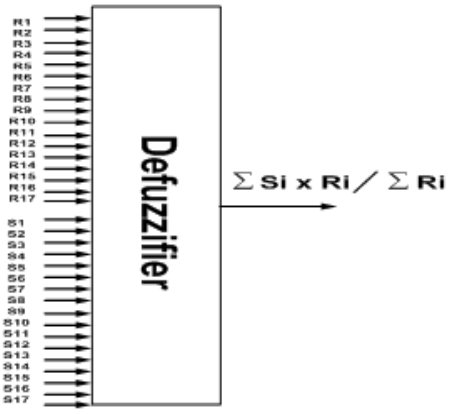

Figure 14 Defuzzifier block for medical diagnosis control system

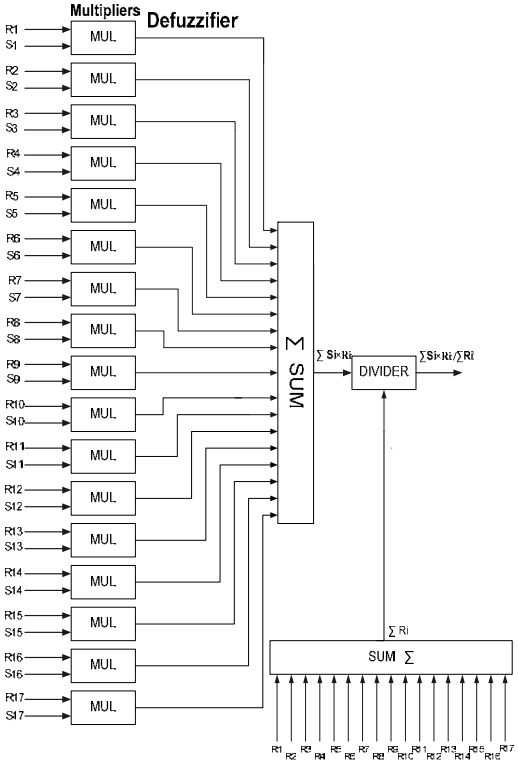

Figure 15 Defuzzifier design for medical diagnosis control system.

IV. RESULTS AND DISCUSSION

The medical diagnosis system is based on fuzzy logic model. It is designed for diagnosis of disease in human brain. This system consists of five input variables: protein, red blood cells, lymphocytes, neutrophils and eosinophils. The rule base of this system is used to determine the three output parameter value: normal, haemorhage, brain tumor, according to the five input values.

Five fuzzifiers and three defuzzifiers are used in this system.
Calculation has been made for the input values, PROTEIN=450, RED BLOOD CELL=3.02, LYMPHOCYTES=64.8, NEUTROPHILS=2.54 and EOSINOPHILS=4.87.
Ten linguistics variables values are given by five fuzzifiers. Inference engine uses these values to apply seventeen inference rules.
MATLAB-simulation is used by applying seventeen rules. Fig.16. shows the MATLAB- rule viewer and simulation result.

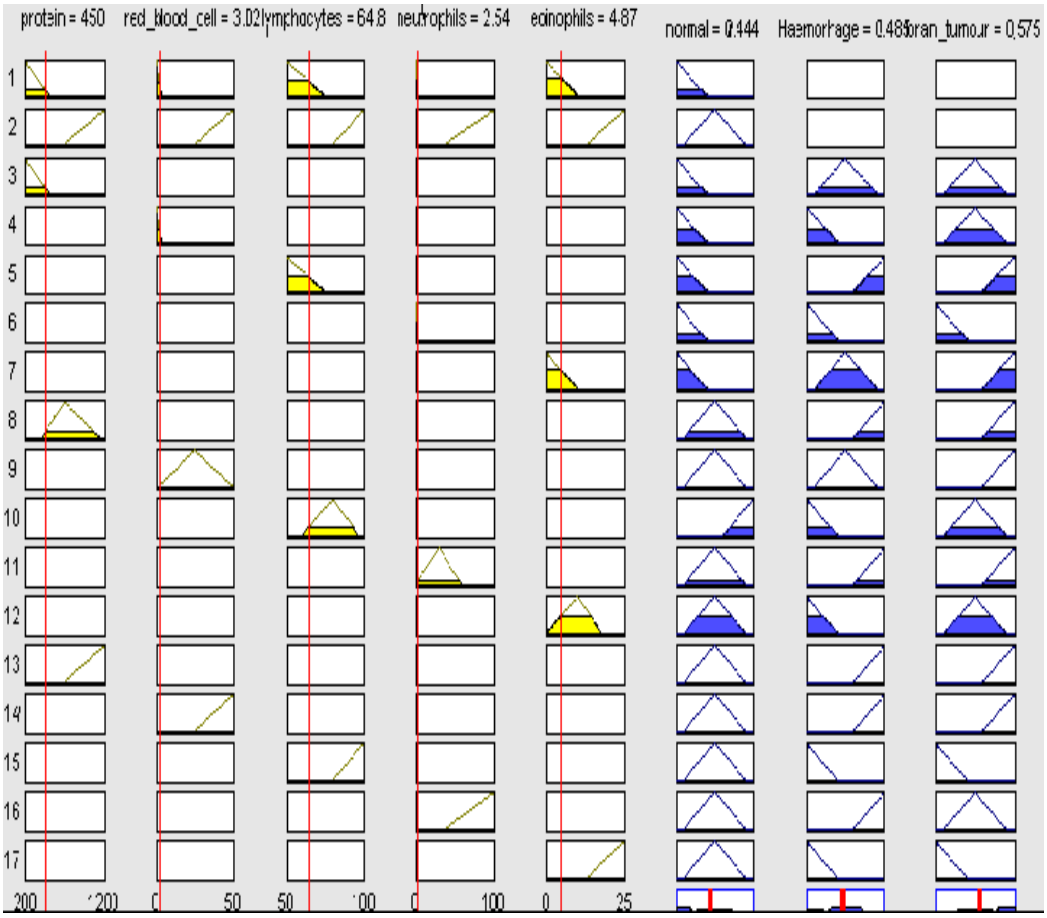

Figure 17. MATLAB- rule viewer and simulation result for fuzzy logic medical diagnosis control system

Fig.17 (a to δ) show all the dependencies of the output variables on the input variables.

Fig.17(a) shows that the normal depends on the protein and does not depend on the red blood cell.

Fig.17(b) shows that the normal only depends on lymphocytes.

Fig.17(c) shows that the normal depends on the protein and after some values it become constant and it depends very little on neutophils.

Fig.17(d) shows that the normal depends on both protein and eosinophils and after some values of both inputs it become constant.

Fig.17(e) indicate that the normal only depends on lymphocytes and red blood cell has no effect on it.

Fig.17(f) indicates that the normal slightly depends on red blood cell and become constant after some values and it does not depends on neutrophils.

Fig.17(g) shows that the normal depends on red blood cell and also slightly on eosinophils and become constant after some values of input.

Fig.17(h) shows that the normal only depends on lymphocytes but does not on neutrophils.

Fig.17(i) indicates that the normal depends on lymphocytes and slightly on eosinophils.

Fig.17(j) shows that the normal depends on eosinophils but does not depend on neutrophils.

Fig.17(k) shows that the haemorhage depends on both the inputs; red blood cell and protein.

Fig.17(l) shows that the haemorhage depends on both inputs; protein and lymphocytes.

Fig.17(m) shows that the haemorhage depends on both inputs; protein and neutrophils.

Fig.17(n) shows that the haemorhage depends on protein but slightly depends on eosinophils.

Fig.17(o) shows that the haemorhage depends on lymphocytes as well as red blood cell.

Fig.17(p) shows that the haemorhage depends on red blood cell but it nearly does not depend on neytrophils.

Fig.17(q) shows that the haemorhage depends on both inputs; red blood cell and eosinophils.

Fig.17(r) shows that the neutrophils has nearly no effect on haemorhage but lymphocytes has effect on haemorhage after a specific range.

Fig.17(s) shows that the haemorhage depends on both inputs; lymphocytes and eosinophils.
Fig.17(t) shows that the neutrophils has nearly no effect on haemorhage but eosinophils has effect on haemorhage after a specific range.
Fig. 17 (u) shows that the brain tumor has nearly same dependence on protein and red blood cell.
Fig. 17 (v) shows that the brain tumor does not depends on protein but shows some dependence on lymphocytes after a specific range.
Fig. 17 (w) shows that the brain tumor does not depends on protein but shows a very little dependence on neutrophils.
Fig. 17 (x) shows that the brain tumor does not depends on protein but shows dependence on eosinophils after a specific range.
Fig. 17 (y) shows that the brain tumor does not depend on red blood cell but shows dependence on lymphocytes after a specific range.
Fig. 17 (z) shows that the brain tumor does not depend on red blood cell but shows a very little dependence on neutrophils.
Fig. 17 (α) shows that the brain tumor does not depends on red blood cell but shows dependence on eosinophils after a specific range.
Fig. 17 (β) shows that the brain tumor depends very little on neutrophils and also depends on lymphocytes after a specific range.
Fig. 17 (γ) shows that the brain tumor depends nearly equal on lymphocytes and eosinophils.
Fig. 17 (δ) shows that the brain tumor depends very little on neutrophils and also on eosinophils after a few range.

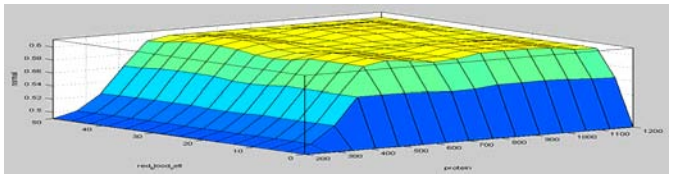

Figure 17 (a). Plot between protein-red blood cell-normal

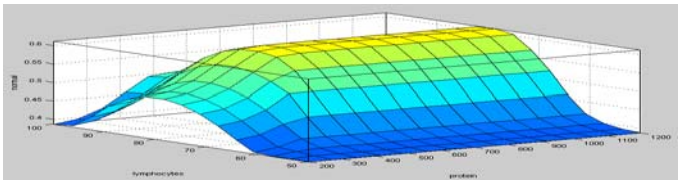

Figure 17 (b). Plot between protein-lymphocytes-normal

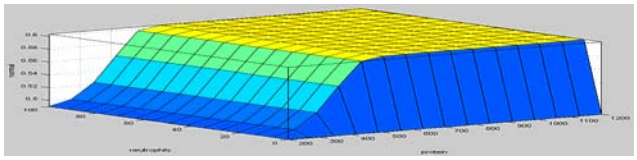

Figure 17 (c). Plot between protein-neutrophils-normal

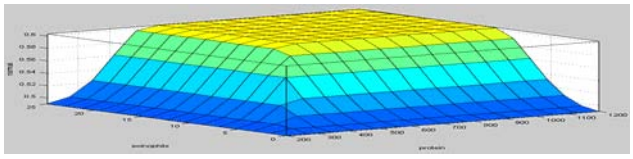

Figure 17 (d). Plot between protein-eosinophils-normal

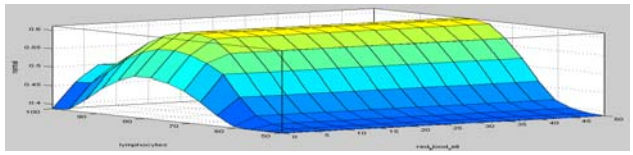

Figure 17 (e). Plot between red blood cell-lymphocytes-normal

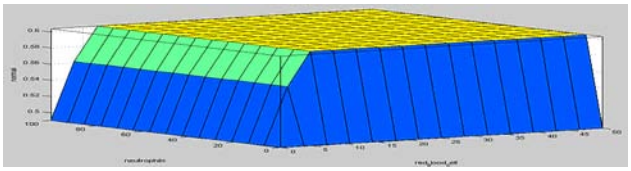

Figure 17 (f). Plot between red blood cell-neutrophils-normal

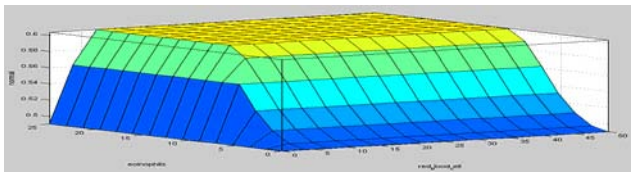

Figure 17 (g). Plot between red blood cell-eosinophils-normal

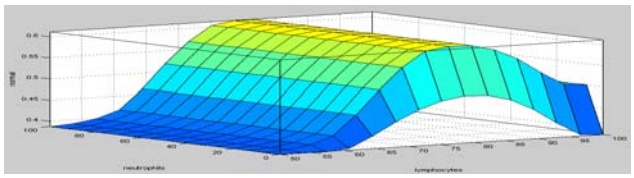

Figure 17 (h). Plot between lymphocytes-neutrophils-normal

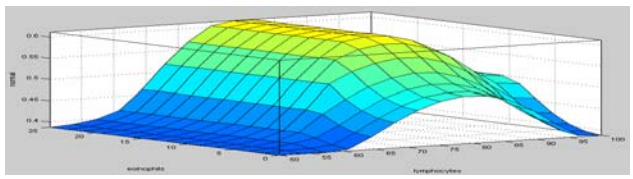

Figure 17 (i). Plot between lymphocytes-eosinophils-normal

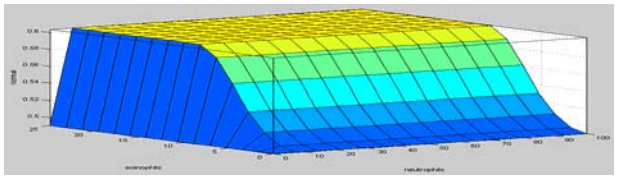

Figure 17 (j). Plot between neutrophils-eosinophils-normal

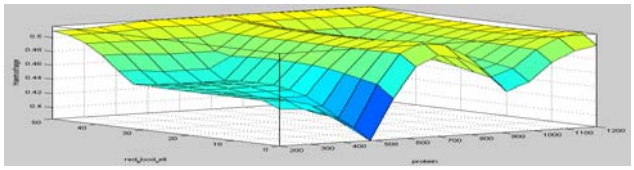

Figure 17 (k). Plot between protein-red blood cell-haemorhage

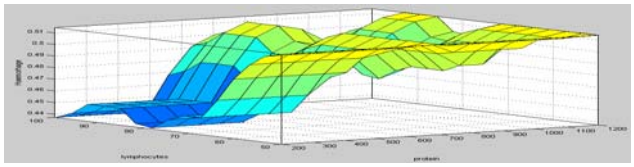

Figure 17 (l). Plot between protein-lymphocytes-hemorrhage

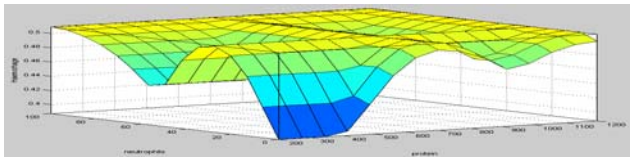

Figure 17 (m). Plot between protein-neutrophils-hemorrhage

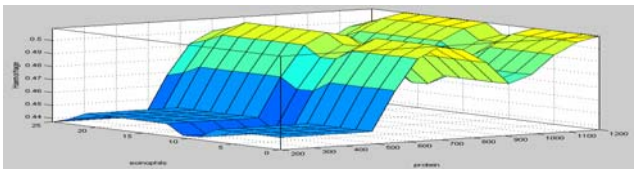

Figure 17 (n). Plot between protein-eosinophils-hemorrhage

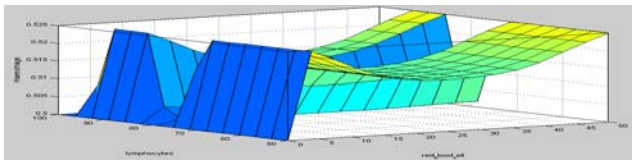

Figure 17 (o). Plot between red blood cell-lymphocytes-haemorhage

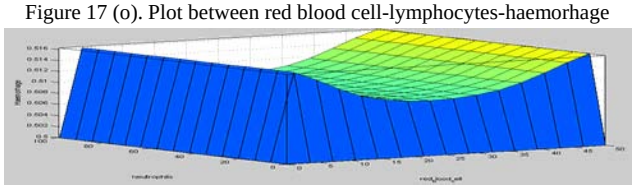

Fig. 17 (p). Plot between red blood cell-neutrophils-

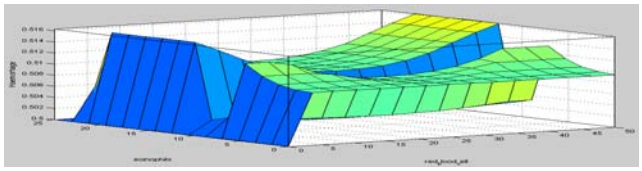

Figure 17 (q). Plot between red blood cell-eosinophils-haemorhage

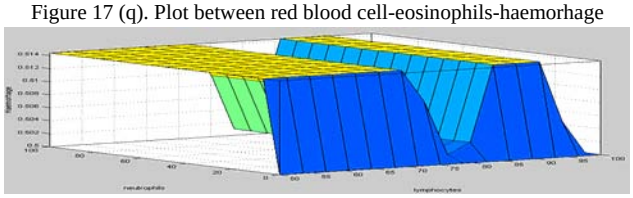

Figure 17 (r). Plot between lymphocytes-neutrophils-haemorhage

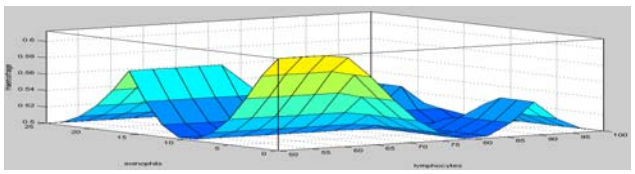

Figure 17 (s). Plot between lymphocytes-eosinophils-haemorhage

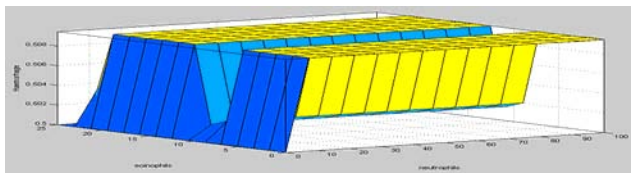

Figure 17 (t). Plot between neutrophils-eosinophils-haemorhage

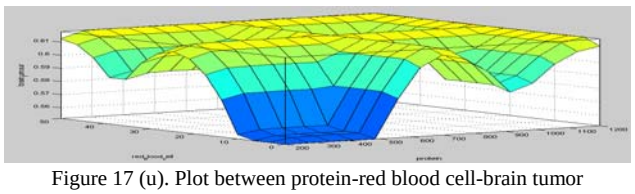

Figure 17 (u). Plot between protein-red blood cell-brain tumor

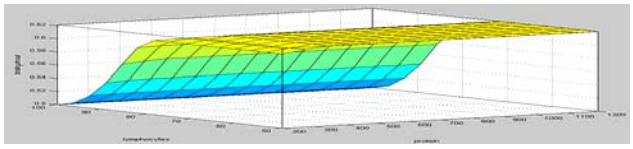

Figure 17 (v). Plot between protein-lymphocytes-brain tumor

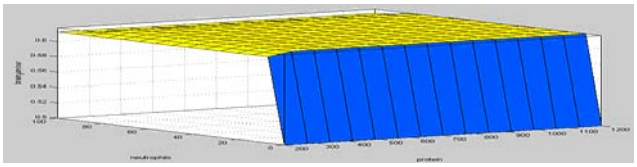

Figure 17 (w). Plot between protein-neutrophils-brain tumor

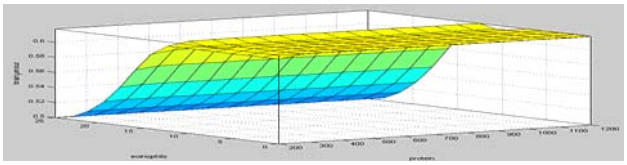

Figure 17 (x). Plot between protein-eosinophils-brain tumor

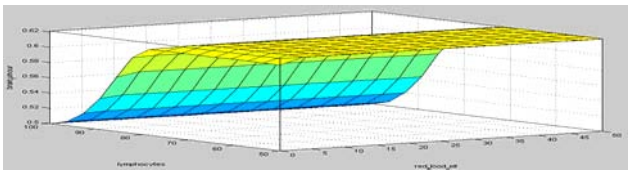

Figure 17 (y). Plot between red blood cell-lymphocytes-brain tumor

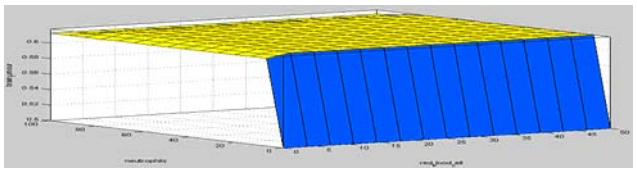

Figure 17 (z). Plot between red blood cell-neutrophils-brain tumor

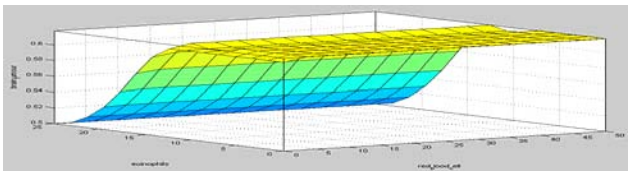

Figure 17 (α). Plot between red blood cell-eosinophils-brain tumor

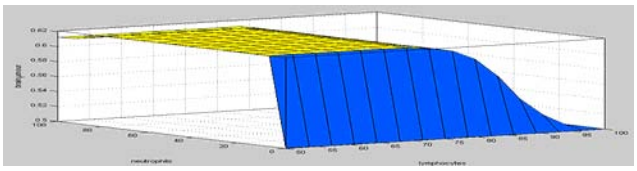

Figure 17 (β). Plot between lymphocytes-neutrophils-brain tumor

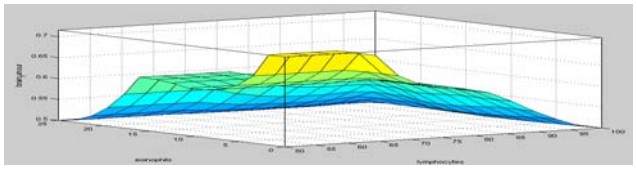

Figure 17 **(γ).** Plot between lymphocytes-eosinophils-brain tumor

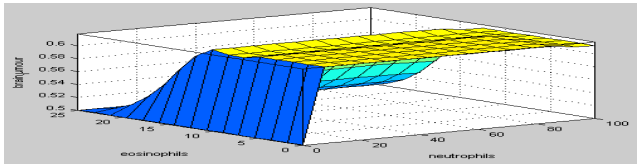

Figure 17 (δ). Plot between neutrophils-eosinophils-brain tumor

Figure 17 (a to δ) MATLAB simulation plots for fuzzy logic medical diagnosis control system

The comparison between calculated and simulated results is given in Table 5.

TABLE 5 COMPARISON BETWEEN CALCULATED AND SIMULATED RESULT

Results	Normal	Haemorhage	Brain tumor
MATLAB Simulation	0.444	0.485	0.575
Calculated Values	0.432	0.464	0.6

The MATLAB results were found by simulator of fuzzy logic tool box in the MATLAB simulator. The plots shown above in the figure 17 (a to δ) give the input output dependences. One plot at a time shows the relation between any two inputs with one output. All the outputs normal, haemorhage and brain tumor show the dependences on inputs.

V. CONCLUSION AND FUTURE WORK

Both the design model and simulation result are same. The designed system can be extended for any number of inputs. Normal, hemorrhage and the brain tumor all depend on the inputs protein, red blood cell, lymphocytes, neutrophils and eosinophils. We can define this system for any number of inputs. As the inputs are the blood cells and the designed system use five blood cells as inputs, similarly we can define this system more than five 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.

ACKNOWLEDGEMENT

This research work was carried out in the laboratories of Electronics Department and the Department of Computer Science GC University, Lahore Pakistan. We are thankful to all personals for their co-operation and involvement to give us experimental convenience.

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