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A Fuzzy Expert System For Pathological Investigation and Diagnosis of Jaundice

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Abstract: With increase in the use of digital equipments in healthcare the volume of the medical knowledge is improving tremendously. Determination of useful knowledge from the available knowledge is becoming challenging. It is becoming inevitable to replace conventional data analysis techniques with more efficient and effective computer based analysis techniques.

In this paper, we present a fuzzy expert system for the pathological investigation of jaundice. The developed system has eight input variables (Bili_T, Bili_D, Bili_ID, AST, ALT, ALP, HB and RC) and one output variable L_D. The output variable is a value from 1 to 11 representing various causes of Jaundice.
The system uses Mamdani interface method. The system is designed in MATLAB software. The developed system can prove to be very useful in comparison with other traditional diagnostic system as it is faster, cheaper and more reliable.

Keyword: Fuzzy Expert System, Diagnosis of Jaundice, Pathological Investigation

I. INTRODUCTION

With tremendous improvements in healthcare knowledge system, determination of the useful knowledge from the available knowledge is challenging task. In diagnosis of the disease, use of computer based analysis are becoming inevitable, hence effective and essential computer based system is the need of time. Various data analysis techniques such as data abstraction, machine learning and expert system can be effectively applied to the medical data [7, 8, 9].

Use of Artificial intelligence methods in various fields including medical applications is gaining popularity. The medical diagnosis of the disease involves several levels of uncertainty and imprecision. Fuzzy logic deals with imprecision and uncertainty by introducing partial values between true and false. Fuzy logic render precise what is imprecise in the field of medicine [10, 11].

Liver is the largest internal organ in the human body, plays a major role in metabolism and serving several vital functions. Cases of liver diseases are continually increasing due to various reasons such as inhalation of harmful gases, consumption of alcohol, and intake of excessive drugs [1, 2, 3]. There are many forms of liver diseases. Liver diseases are difficult to predict at earlier stage due to lack of symptoms.
The diagnosis of liver diseases is based on different pathological tests. In this paper we attempt to apply fuzzy logic to design expert system for the pathological investigation and diagnosis of jaundice which may help doctors to diagnose jaundice and help deciding its treatment [4, 5,6].

This system has eight input variables (SBT, Bili_D, Bili_ID, AST, ALT, ALP, HB & RC) and one output variable (L_D). The output variable is a value from 1 to 11 representing various causes of Jaundice. This system uses Mamdani interface method and simulation applied in MATLAB fuzzy logic toolbar. This paper is organized as follows, Structure of fuzzy logic system is introduced in Section II, Design of the system is presented in Section III, Result & Discussions are presented in section IV and conclusion & future work in Section V.

II. STRUCTURE OF FUZZY EXPERT SYSTEM

Fuzzy logic system (Figure 1) consists of the following components [13].

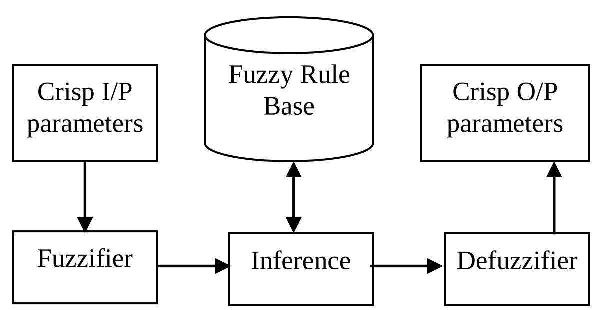

Figure 1: General structure of fuzzy logic system.

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1. Fuzzification: In this stage the crisp sets are transformed into Lingustic concepts with the help of membership functions.

2. Inference Engine: After fuzzification of the inputs, the fuzzified input sets are passed to the inference engine. Inference engine processes these inputs with the help of the rules retrieved from the rule base.

3. Defuzzificztion: The output of the fuzzy inference will always be a fuzzy set. This fuzzy output is converted to crisp values by the defuzzifier with the help suitable membership function.

III. SYSTEM DESIGN

In this section we show the fuzzy expert system designing, membership functions, fuzzy rule base, fuzzification and defuzzification.

The first step of fuzzy expert system is determination of input & output variables. There are eight input variables and one output variable.

In the second step membership functions (MF) of all the variables which determine the membership of objects to fuzzy sets are designed.

3.1. Input Variables

3.1.1. SBT: "Serum Bilrubin".

Bilrubin- an orange bile pigment produce by the breakdown of heme and reduction of biliverdin excreted in bile and urine. Eleveted levels may indicate certain diseases.

This input variable has three fuzzy sets, high, intermediate and low. Membership functions of these fuzzy sets are trapezoidal and triangular. Fuzzy sets range of SBT is shown in Table 1. Fuzzification of the SBT is done by the below function created by the domain expert.

$$SBT(x) = \begin{cases} 0 & x < 1.0 \\ \dfrac{2.2 - x}{1.5} & 0.7 < x < 2.2 \\ 1 & x > 2.0 \end{cases}$$

The membership functions for fuzzy sets are shown in fig 2

Table 1: Fuzzy sets range of SBT

Input Field	Range	Fuzzy Set
SBT	< 1.0	Negative
	1.0 – 2.0	May be negative or positive
	> 2.0	Positive

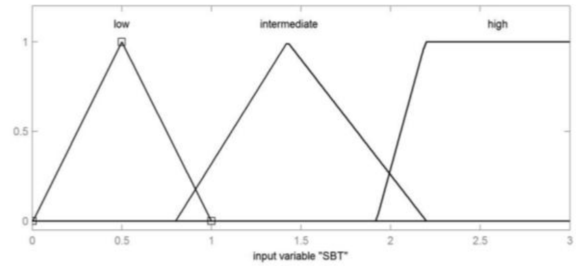


Figure 2: Membership Functions for SBT

3.1.2 Bili_D: "Bilirubin direct".

Also called conjugated, bilirubin that has been conjugated mainly to glucuranic acid in the liver. High blood levels indicate obstructive or hepatocellular origin of the jaundice .

This input variable has three fuzzy sets high, intermediate and low .Membership functions of these fuzzy sets are triangular and trapezoidal. Fuzzy sets range of Bili-D is shown in table 2. Fuzzyfication of these variables is done by the following function

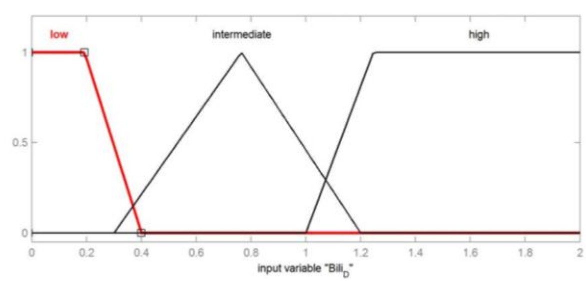
$$Bili\_D(x) = \begin{cases} 0 & x < 0.3 \\ \dfrac{1.2 - x}{1.0} & 0.2 < x < 1.2 \\ 1 & x > 1.0 \end{cases}$$

The membership functions for fuzzy sets are shown in figure 3.

Table 2: Fuzzy sets range of Bili_D

Input Field	Range	Fuzzy Set
Bili_D	< 0.3	Negative
	0.3 - 1.0	May be negative or positive
	> 1.0	Positive

Figure 3: Membership Functions for Bili_D



3.1.3. Bili_ID: Bilirubin Indirect.

Bilirubin that has not been conjugated in the liver, a high level of it in the blood is indicative of hemolysis or lack of bilirubin clearance by the liver.

This input variable has three fuzzy sets, high, intermediate and low .Membership functions of these fuzzy sets are triangular and trapezoidal . fuzzy sets range of Bili-ID is shown in table 3. Fuzzification of this variable is done by the following function.

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$$Bili\_ID(x)=\begin{cases}0 & x<0.7\\ \dfrac{1.2-x}{0.7} & 0.5<x<1.2\\ 1 & x>1.0\end{cases}$$

The membership functions for fuzzy sets are shown in fig. 4.

Table 3: Fuzzy sets range of Bili_ID

Input Field	Range	Fuzzy Set
Bili_ID	< 0.7	Negative
	0.7 - 1.0	May be negative or positive
	> 1.0	Positive

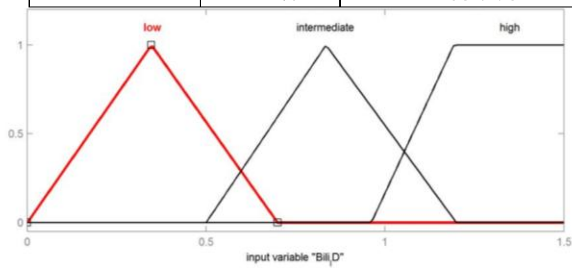

Figure 4: Membership Functions for Bili_ID

3.1.4. AST: Aspartate aminotransferase

The AST test measures levels of AST, an enzyme released into blood. This input variable has three fuzzy sets, high, intermediate and low. Membership functions of these fuzzy sets are triangular and trapezoidal. Fuzzy sets range of AST is shown in table 4. Fuzzification of this variable is done by the following functions.

$$AST(x)=\begin{cases}0 & x<25\\ \dfrac{35-x}{17} & 20<x<37\\ 1 & x>35\end{cases}$$

The membership functions for the fuzzy sets are shown in fig. 5.

Table 4: Fuzzy sets range of AST

Input Field	Range	Fuzzy Set
AST	< 25	Negative
	25 – 37	May be negative or positive
	> 35	Positive

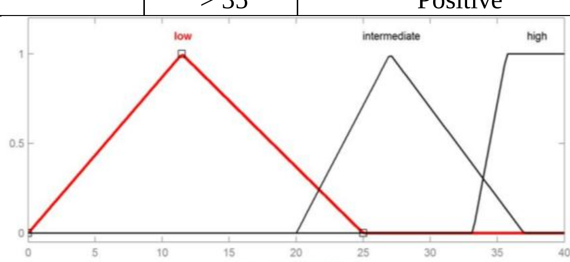

Figure 5: Membership Functions for AST

3.1.5. ALT: "Alanine aminotransferase"

An ALT test measures the amount of this enzyme in the blood . ALT is formed mainly in the liver . This input variable has three fuzzy sets, high, intermediate and low. Membership functions of these fuzzy sets are triangular and trapezoidal. Fuzzy set range of ALT is shown in the table 5. Fuzzification of this variable is done by the following functions .

$$ALT(x)=\begin{cases}0 & x<25\\ \dfrac{37-x}{17} & 20<x<37\\ 1 & x>35\end{cases}$$

The membership functions for the fuzzy sets are shown in fig. 6.

Table 5: Fuzzy sets range of ALT

Input Field	Range	Fuzzy Set
ALT	< 25	Negative
	25 – 37	May be negative or positive
	> 35	Positive

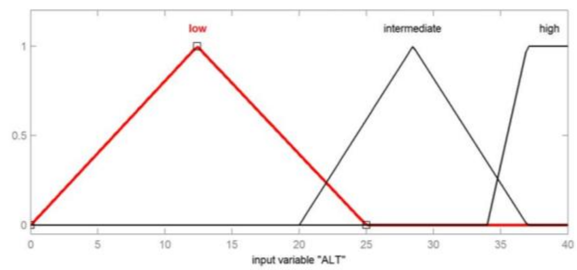

Figure 6: Membership Functions for ALT

3.1.6. ALP: "alkaline phosphatase"

ALP test measures the amount of the enzyme ALP in the blood. APL is produced primarily in the liver and in bone. . This input variable has three fuzzy sets, high, intermediate and low. Membership functions of these fuzzy sets are triangular and trapezoidal. Fuzzy set range of ALP is shown in the table 7. Fuzzyfication of this variable is done by the following functions.

$$ALP(x)=\begin{cases}0 & x<85\\ \dfrac{130-x}{55} & 75<x<130\\ 1 & x>125\end{cases}$$

The membership functions for the fuzzy sets are shown fig. 7.

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Table 6: Fuzzy sets range of ALP

Input Field	Range	Fuzzy Set
ALP	< 85	Negative
	75 – 125	May be negative or positive
	> 125	Positive

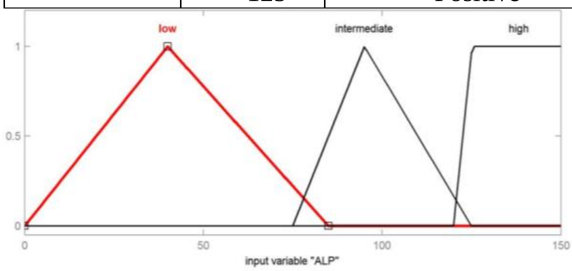

Figure 7: Membership Functions for ALP

3.1.7. HB: Stands for "Hemoglobin"

Hemoglobin is a protin in the side red blood cells that carries oxygen throughout the body. Hemoglobin test reveals how much hemoglobin is in a person's blood . . This input variable has three fuzzy sets, high, intermediate and low. Membership functions of these fuzzy sets are triangular and trapezoidal. Fuzzy set range of HB is shown in the table 7. Fuzzification of this variable is done by the following functions.

$$HB(x) = \begin{cases} 0 & x > 14 \\ \dfrac{14-x}{4} & 10 < x < 14 \\ 1 & x < 11 \end{cases}$$

The membership functions for the fuzzy sets are shown in fig. 8.

Table 7: Fuzzy sets range of HB

Input Field	Range	Fuzzy Set
HB	> 13	Negative
	10 – 13	May be negative or positive
	< 11	Positive

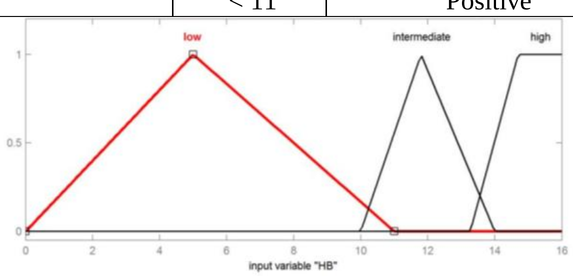

Figure 8: Membership Functions for HB

3.1.8. RC: "Reticulate count"

A reticulate count is a blood test performed to access the bodys production of immature red blood cells. RC test is usually performed when patients are evaluated for animia . This input variable has three fuzzy sets, high, intermediate and low. Membership functions of these fuzzy sets are triangular and trapezoidal. Fuzzy set range of RC is shown in the table 8. Fuzzification of this variable is done by the following functions

$$RC(x) = \begin{cases} 0 & x > 3 \\ \dfrac{3-x}{2.5} & 0.5 < x < 3 \\ 1 & x < 0.5 \end{cases}$$

The membership functions for the fuzzy sets are shown in table 8.

Table 8: Fuzzy sets range of RC

Input Field	Range	Fuzzy Set
RC	> 3 %	Negative
	0.5 % – 3.0 %	May be negative or positive
	< 0.5 %	Positive

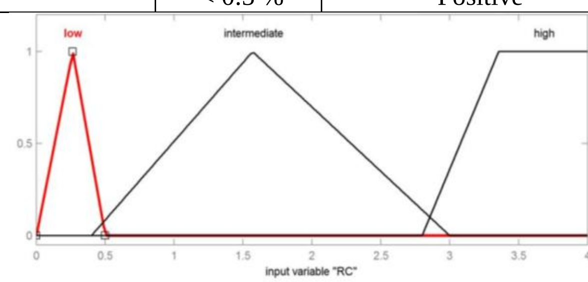

Figure 9: Membership Functions for RC

3.2 Output Variable

The goal of the system is to identify the jaundice causes . The output variable L-D which stands for liver disease and is a value from 1 to 11 , representing various causes of jaundice such as colestatic injury, hepatic injury , Dubin Johnson syndrome, Hemolytic animia, Gilbert syndrome and normal liver condition.

Table 9 identifies these fuzzy sets and its range . The membership function for fuzzy set L_D are triangular and shown in fig. 10.

Table 9: Fuzzy sets range of output variable L_D

Output Variable	Range	Fuzzy Set
L_D	0-1	Normal liver condition
	1-2	Hemolytic Animia low Risk
	2-3	Hemolytic Animia high Risk
	3-4	Colestatic injury low Risk
	4-5	Colestatic injury high Risk
	5-6	Hepatocellular low Risk
	6-7	Hepatocellular high Risk
	7-8	Gilbert Syndrom low Risk

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	8-9	Gilbert Syndrom high Risk
	9-10	Dubin Johnson Syndrom low Risk
	10-11	Dubin Johnson Syndrom high Risk

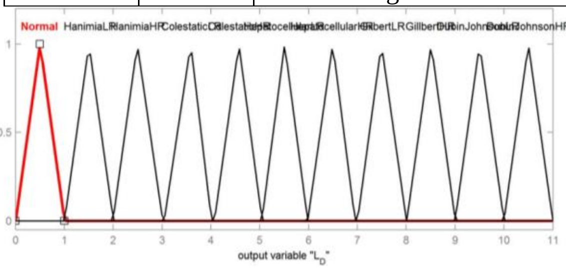

Figure 10: Membership Functions for output variable L_D

3.3. Fuzzy Rule Base

The rule base is determined by the help of Pathologist of government medical college, Akola. The rule base consists of 33 rules that determine the causes of jaundice on liver by evaluating the input variables. The rule base is shown in table VI

3.4. Fuzzification and Defuzzification

The designed system uses mamdani model for interface mechanism. This system contains only AND operator hence the method is minimum. Implication method is minimum. Aggregation method between the rules is maximum, hence fuzzification method is max-min and Defuzzification method used in this system is Centroid.

IV. RESULT AND DISCUSSION

Fuzzy expert system for diagnosing jaundice has been developed. The study evaluated the diagnosis of twenty patients using this system and the results obtained are in the predefined limits set by the domain expert. Table 10 and Figure 11 show one of the tested value.

Table 10: Rule base of the system

Rule no.	SB	BD	BID	AST	ALT	ALP	HB	RC	Liver_D
1	L	ANY	ANY	ANY	ANY	ANY	ANY	ANY	NORMAL
2	I	I	L	L	L	I	H	H	COLESTATIC LR
3	I	I	L	L	L	H	H	H	COLESTATIC HR
4	I	H	L	L	L	I	H	H	COLESTATIC HR
5	I	H	L	L	L	H	H	H	COLESTATIC HR
6	H	I	L	L	L	I	H	H	COLESTATIC LR
7	H	I	L	L	L	H	H	H	COLESTATIC HR
8	H	H	L	L	L	I	H	H	COLESTATIC LR
9	H	H	L	L	L	H	H	H	COLESTATIC HR
10	I	I	L	I	I	L	H	H	HEPTOCELLULAR LR
11	I	I	L	H	H	L	H	H	HEPTOCELLULAR HR
12	I	H	L	I	I	L	H	H	HEPTOCELLULAR LR
13	I	H	L	H	H	L	H	H	HEPTOCELLULAR HR
14	H	I	L	I	I	L	H	H	HEPTOCELLULAR LR
15	H	I	L	H	H	L	H	H	HEPTOCELLULAR HR
16	H	H	L	I	I	L	H	H	HEPTOCELLULAR LR
17	H	H	L	H	H	L	H	H	HEPTOCELLULAR HR
18	I	I	L	L	L	L	H	H	DJ SYNDROME LR
19	I	H	L	L	L	L	H	H	DJ SYNDROME HR
20	H	I	L	L	L	L	H	H	DJ SYNDROME LR
21	H	H	L	L	L	L	H	H	DJ SYNDROME HR
22	I	L	I	L	L	L	H	H	GILBERTSYN LR
23	I	L	H	L	L	L	H	H	GILBERTSYN HR
24	H	L	I	L	L	L	H	H	GILBERTSYN LR
25	H	L	H	L	L	L	H	H	GILBERTSYN HR
26	I	L	I	L	L	L	I	I	H.ANIMIA LR
27	I	L	H	L	L	L	I	I	H.ANIMIA LR
28	H	L	I	L	L	L	I	I	H.ANIMIA LR
29	H	L	H	L	L	L	I	I	H.ANIMIA LR
30	H	L	I	L	L	L	L	L	H.ANIMIA HR
31	H	L	H	L	L	L	L	L	H.ANIMIA HR
32	I	L	I	L	L	L	L	L	H.ANIMIA HR
33	I	L	H	L	L	L	L	L	H.ANIMIA HR

Table 11: Tested values

SBT	Bili_D	Bili_ID	AST	ALT	ALP	HB	RC	L_D
1.2	0.2	1.5	20	20	20	12	0.8	1.5

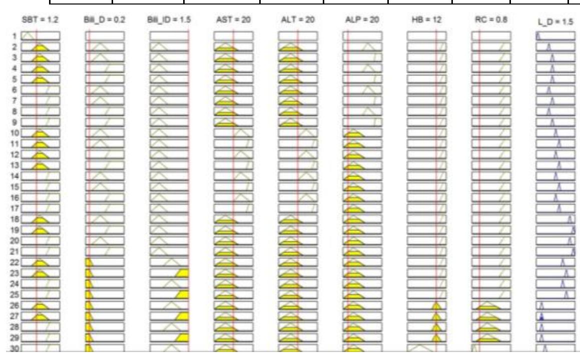

Figure 11: Result of Tested values

Figure 12 and 13 shows surface viewer of some of the field as follows:

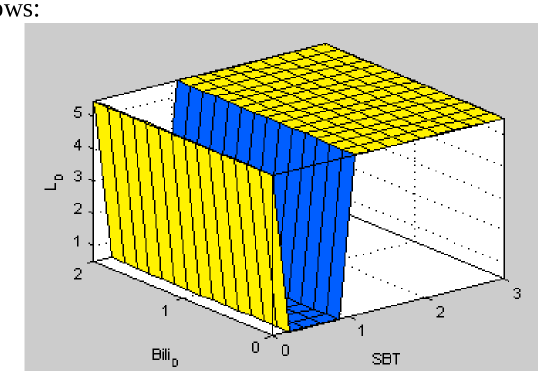

Figure 12: Surface viewer of SBT versus Bili_ID

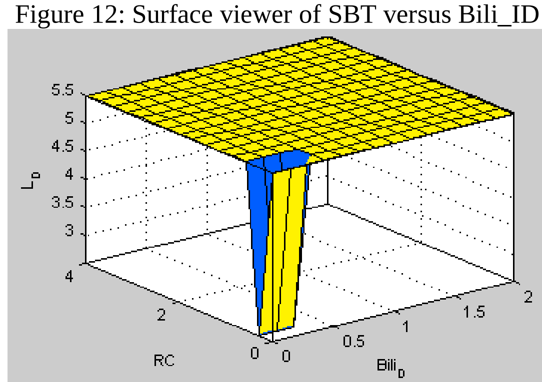

Figure 13: Surface viewer of Bili_ID versus RC

V. CONCLUSION AND FUTURE WORK

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This paper describes design of fuzzy expert system for the pathological investigation and diagnosis of Jaundice, which can be used by the doctors for the jaundice treatment. The system design is based on membership functions, input, output variables and the rule base.

In this system fuzzy logic enhance the reasoning in dealing with fuzzy data and the expert system uses the rules designed by the domain expert to diagnose patient's illness based on the pathological tests. Combination of expert system and fuzzy logic could increase the performance. In future this system can be applied for the other liver diseases.

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