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FUZZY EXPERT SYSTEM FOR THE PROGNOSIS OF LIVER CIRRHOSIS

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ABSTRACT—

Decision support through expert systems becomes part of everyday life. The aim of this study is to design a fuzzy expert system for the diagnosis of Cirrhosis which is one of the common diseases of the liver. The designed system is based on the sequential combination of the Child Pugh score. Input fields are based on scoring system of Child pugh score and the output field refers to the risk of cirrhosis. The Child-Pugh score (or its associated Child-Pugh grade) is often used as a means to give a very general description of the clinical state of patients with cirrhosis of the liver, and to indicate the severity of the condition. CTP is used to assess the likelihood of mortality in cirrhotic patients who were undergoing portosystemic shunt surgery to prevent further variceal bleeds. Each patient was assigned a Child's grading (of A, B or C) to stratify the individual with regard to risk of death due to the procedure. Child's grade A patients were believed to have the best prognosis, and Child's grade C patients the worst. Five variables are considered: presence of ascites, encephalopathy, serum levels of albumin, total billirubin, and prolongation of the clotting time. Each of these variables is assigned a score between 1 and 3 according to its severity or degree of abnormality. The system uses Mamdani Inference method. The results obtained from the designed system are compared with the actual data of patients in the database and observed results of the designed system are well within the limits set by the domain expert. The system can be used as decision support for the prediction of the cirrhosis and can avoid the need of the liver biopsy.

Keywords: Expert System, Fuzzy, Medical Diagnosis.

I.INTRODUCTION

Cirrhosis is a serious disease of the liver which replaces healthy liver tissues with scar tissue. The scar tissue blocks the flow of blood in the liver and slows down the vital functions of liver. Various possible causes of cirrhosis are:

A. Alcoholic Disease :

Alcohol injuries may affect the normal functioning of liver by blocking the metabolism of fat, proteins and carbohydrates.

B. Hepatitis:

Hepatitis C, a bloodbourne infection, can damage the liver and eventually lead to cirrhosis. Cirrhosis can also be caused by hepatitis B and D.

C. Non-alcoholic:

NASH is more likely to occur with people who are obese, diabetes patients, those with high blood lipid (fat) levels, as well as individuals with hypertension (high blood pressure). NASH, in its early stages, begins with the accumulation of too much fat in the liver.

D. Autoimmunehepatitis:

The person's own immune system attacks healthy organs in the body as though they were foreign substances. Eventually the patient can develop cirrhosis.

E. Blockage of bile duct:

Some conditions and diseases, such as cancer of the bile ducts, or cancer of the pancreas can block the bile ducts, increasing the risk of cirrhosis.

F. Other diseases and conditions:

Some of the other diseases and conditions that can contribute to cirrhosis are:

- Cystic fibrosis.
- Primary sclerosing cholangitis - hardening and scarring of the bile ducts.

- Galactosemia - inability to process sugars in milk- a parasite commonly found in some developing countries
- Glycogen storage disease - problems in the storage and energy release vital for cell function.

G. Some genetic conditions:

- *Hemochromatosis*- iron accumulates in the liver and other parts of the body.
- *Wilson's disease* -copper accumulates in the liver and other parts of the body.

H. Inherited diseases:

Certain inherited diseases such as Alpha-1 antitrypsin deficiency, Glycogen storage diseases, Wilson disease and cystic fibrosis can cause Cirrhosis. Complication of Cirrhosis includes edema and ascites, bleeding from varices, hepatopulmonary syndrome and liver cancer. The conformation can be done by the liver biopsy, but biopsy may cause complications. Several non invasive tests which includes routine laboratory test can predict cirrhosis.
The aim of this research is to design a Fuzzy expert system using CTP score to predict diagnostic accuracy of cirrhosis. The investigation of cirrhosis involves uncertainty and imprecision, hence fuzzy logic is the most suitable tool for the development of this system. This paper is organized as follows:

- General structure of fuzzy logic in section II
- Design of system in section III
- Input variables are present in Section III.A
- Output variable is presented in Section III.B
- Fuzzy rule base is presented in Section IV

II. GENERAL STRUCTURE OF FUZZY LOGIC

Fuzzy logic system as seen in Figure 1 consists of the following modules:

1) Fuzzification: It is the operation of transforming a crisp set to a fuzzy set. The operation translates crisp input or measured values into linguistic concepts by using suitable membership functions.

A. *Inference Engine and Rule base:* Once the inputs are fuzzified, the corresponding inputs fuzzy sets are passed to the inference engine that processes current inputs using the rules retrieved from the rule base.

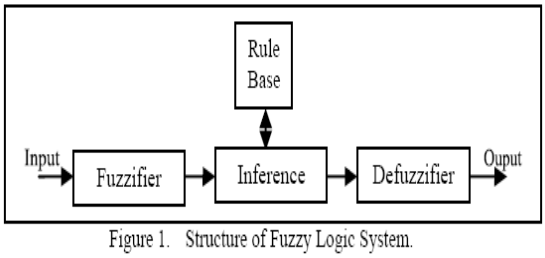

Figure 1. Structure of Fuzzy Logic System.

Defuzzification: At the output of the fuzzy inference there will always be a fuzzy set that is obtained by the composition of the fuzzy sets output by each of the rules. In order to be used in the real world, the fuzzy output needs to be interfaced to the crisp domain by the defuzzifier by using suitable membership functions

III. Design Of The System

In this section we show the fuzzy expert system designing, Membership functions, fuzzy rule base, fuzzification and defuzzification. The first step of the system designing is determination of input and output variables. There are three input variables and one output variable. Next the membership functions of all the variables are designed. At first the input variables with their membership functions are described. In second step output variable with its membership functions are described. In second step output variable with its membership functions are described. Rules of the system, fuzzification and defuzzification is explained in the next section.

A. INPUT VARIABLE:

1) Ascites:

Ascites is the accumulation of fluid in peritoneal cavity. This input variable has three fuzzy sets, are score1, score2, score3. Membership functions of these fuzzy sets are trapezoidal and Triangular. Table1 identifies fuzzy sets range and Fig.2 identifies membership functions of them.

I/P Field	Range	Fuzzy Set	Description
ASCITES	<1.5	Score1	Low Risk
	1-3	Score2	Moderate Risk
	>2.75	Score3	High Risk

Table 1: Fuzzy sets of Ascites

Figure2: Membership function for Ascites

$$H_{score1}(x)=\begin{cases}0 & x>2\\ \dfrac{2-x}{2-1} & 1\le x\le 2\\ 1 & x<1\end{cases}$$

$$H_{score2}(x)=\begin{cases}0 & x\le 1\\ \dfrac{x-1}{2-1} & 1<x<3\\ 1 & x=2\\ \dfrac{3-x}{3-2} & 2<x<3\\ 0 & x\ge 3\end{cases}$$

$$H_{score3}(x)=\begin{cases}0 & x<2\\ \dfrac{x-2}{3-2} & 2\le x\le 3\\ 0 & x\ge 3\end{cases}$$

2) Encephalopathy:

The liver does not clear ammonia and related nitrogenous substances from the blood which are carried to the brain affected cerebral functioning; neglect of personal appearance unresponsiveness, forgetfulness , trouble constrating , or change in sleep habbits .This input variable has three fuzzy sets, are score1, score2,score3. Membership functions of these fuzzy sets are trapezoidal and Triangular. Table2 identifies fuzzy sets range and Fig. 4 identifies membership functions of them.

I/P Field	Range	Fuzzy Set	Description
ENCEPHALO-PATHY	0-1	Score1	Low Risk
	1-2	Score2	Moderate Risk
	3-4	Score3	High Risk

Table 2: Fuzzy sets of Encephalopathy

Figure3: Membership function for Encephalopathy

$$H_{score1}(x)=\begin{cases}0 & x>1.5\\ \dfrac{1.5-x}{1.5-1} & 1<x<1.5\\ 1 & x<1\end{cases}$$

$$H_{score2}(x)=\begin{cases}0 & x\le 1\\ \dfrac{x-1}{1.5-1} & 1<x<2\\ 1 & x=1.5\\ \dfrac{2-x}{2-1.5} & 1.5<x<2\\ 0 & x\ge 2\end{cases}$$

$$H_{score3}(x)=\begin{cases}0 & x<1.5\\ \dfrac{x-1.5}{2-1.5} & 1.5\le x\le 2\\ 1 & x>2\end{cases}$$

3) Bilirubin:

Bilirubin is an endogenous anion derived from hemoglobin degradation from the RBC. This input variable has three fuzzy sets, are score1, score2,score3. Membership functions of these fuzzy sets are trapezoidal and Triangular. Table 3 identifies fuzzy sets range and Fig. 4 identifies membership functions of them.

I/P Field	Range	Fuzzy Set	Description
BILIRUBIN	<70	Score1	Low Risk
	70-170	Score2	Moderate Risk
	>170	Score3	High Risk

Table 3: Fuzzy sets of Bilirubin

Figure4: Membership function for bilirubin

$$H_{score1}(x)=\begin{cases}0 & x>120\\ \dfrac{120-x}{120-70} & 70\le x\le 120\\ 1 & x<70\end{cases}$$

$$H_{score2}(x)=\begin{cases}0 & x\le 70\\ \dfrac{x-70}{120-70} & 70\le x\le 170\\ 1 & x=120\\ \dfrac{170-x}{170-120} & 120<x<170\\ 0 & x\ge 170\end{cases}$$

$$H_{score3}(x)=\begin{cases}0 & x<120\\ \dfrac{x-120}{170-120} & 120\le x\le 170\\ 1 & x>170\end{cases}$$

4) Albumin:

Albumin synthesis is an important function of liver approximately 10 g is synthesized and secreted daily with progress. This input variable has three fuzzy sets, are score1, score2,score3. Membership functions of these fuzzy sets are trapezoidal and Triangular. Table 4 identifies fuzzy sets range and Fig. 5 identifies membership functions of them.

I/P Field	Range	Fuzzy Set	Description
ALBUMIN	>35	Score1	Low Risk
	28-35	Score2	Moderate Risk
	<28	Score3	High Risk

Table 4: Fuzzy sets of Albumin

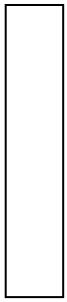

Figure 5: Membership function for Albumin

$$H_{score1}(x)=\begin{cases}0 & x>31\\ \dfrac{31-x}{31-28} & 28\le x\le 31\\ 1 & x<28\end{cases}$$

$$H_{score2}(x)=\begin{cases}0 & x\le 28\\ \dfrac{x-28}{31-28} & 28<x\le 35\\ 1 & x=31\\ \dfrac{35-x}{35-31} & 31<x<35\end{cases}$$

$$H_{score3}(x)=\begin{cases}0 & x<31\\ \dfrac{x-31}{35-31} & 31\le x\le 35\\ 1 & x>35\end{cases}$$

5) INR:

Stands for International Normalized Ratio. PROTIME INR or PT/INR test is used to determine bloods clotting tendency and is major of liver damage.This input variable has three fuzzy sets, are score1, score2,score3. Membership functions of these fuzzy sets are trapezoidal and Triangular. Table 5 identifies fuzzy sets range and Fig. 6 identifies membership functions of them.

I/P Field	Range	Fuzzy Set	Description
INR	<1.7	Score1	Low Risk
	1.8-2.3	Score2	Moderate Risk
	>2.3	Score3	High Risk

Table 5: Fuzzy sets of INR

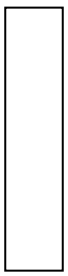

Figure 6: Membership function for INR

$$H_{score1}(x)=\begin{cases}0 & x>2\\ \dfrac{2-x}{2-1.7} & 1.7\le x\le 2\\ 1 & x<1.7\end{cases}$$

$$H_{score2}(x)=\begin{cases}0 & x\le 1.7\\ \dfrac{x-1.7}{2-1.8} & 1.8<x\le 2.3\\ 1 & x=2\\ \dfrac{2.3-x}{2.3-2} & 2<x<2.3\end{cases}$$

$$H_{score3}(x)=\begin{cases}0 & x<2\\ \dfrac{x-2}{2.3-2} & 2\le x\le 2.3\\ 1 & x>2.3\end{cases}$$

B. Output Variable:

The aim of the system is to identify risk status of Cirrhosis. The output is a value from 5 to 15 representing Low risk, Moderate risk & High risk. This output variable has three fuzzy sets Low risk Moderate risk and high risk. These fuzzy sets and its ranges are shown in Table 6. The membership functionsof these fuzzy sets are triangular and trapezoidal and are shown in Figure 7

Output	Range	Fuzzy Set
	5-6	Low Risk
Risk Status	7-9	Moderate Risk
	10-15	High Risk

Table6: Fuzzy set of output variable

IV. Fuzzy Rule Base:

The rule base is determined with the help of an expert doctor. The rule based consist of 300 rules of which 50 are listed below in table 2 These rules determine the risk status by the evolution of input variables.

Rule	Ascites	Encephalopathy	Bilirubin	Albumin	INR	Risk Status
1	Score1	Score1	Score1	Score 1	Score1	Low Risk
2	Score 1	Score 2	Score 1	Score 1	Score1	Low Risk
3	Score 1	Score 1	Score 2	Score 1	Score1	Low Risk
4	Score 1	Score 1	Score 1	Score 2	Score1	Low Risk
5	Score 2	Score 2	Score 1	Score 1	Score1	Moderate Risk
6	Score 1	Score 2	Score 2	Score 1	Score1	Moderate Risk
7	Score 1	Score 1	Score 2	Score 2	Score1	Moderate Risk
8	Score 1	Score 1	Score 1	Score 2	Score2	Moderate Risk
9	Score 1	Score 1	Score 2	Score 2	Score1	Moderate Risk
10	Score 1	Score 1	Score 1	Score 2	Score2	Moderate Risk
11	Score 2	Score 1	Score 1	Score 2	Score2	Moderate Risk
12	Score 2	Score 2	Score 2	Score 1	Score1	Moderate Risk
13	Score 1	Score 2	Score 2	Score 2	Score1	Moderate Risk
14	Score 2	Score 1	Score 1	Score 2	Score2	Moderate Risk
15	Score 2	Score 1	Score 1	Score 3	Score3	HighRisk
16	Score 1	Score 2	Score 1	Score 3	Score3	HighRisk
17	Score 1	Score 1	Score 2	Score 3	Score3	HighRisk
18	Score 1	Score 1	Score 3	Score 2	Score3	HighRisk
19	Score 1	Score 1	Score 3	Score 3	Score2	HighRisk
20	Score 2	Score 3	Score 3	Score 1	Score1	HighRisk

Table 7:Rule Base of the System

V. Result and Discussion

Fuzzy expert system for the risk identification of the Cirrhosis has been developed. The developed system is used to evaluate the study of twenty patients. It is found that the results obtained are in the predefined limits set by the domain expert. Figure 7 shows the result of the tested value.

Figure 7:Result of tested value

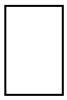

Figure8: Surface Viewer Of Encephalopathy versus Ascites

Figure 9:Surface Viewer Of Billirubin versus Encephalopathy

No	Patients Name	Age	Ascites	Encepthalopathy	Bilirubin	Albumin	INR	Status
1	P	56	Score 2	Score 2	Score 2	Score 2	Score 2	Moderate Risk
2	SWAPNIL	50	Score 1	Score 2	Score 1	Score 2	Score 1	Moderate Risk
3	ARMAAN	75	Score 1	Score 1	Score 2	Score 1	Score 2	Moderate Risk
4	AMAN	70	Score 2	Score 1	Score 1	Score 2	Score 1	Moderate Risk
5	ROHIT	74	Score 1	Score 2	Score 1	Score 1	Score 2	Moderate Risk
6	LUBENA	68	Score 2	Score 1	Score 2	Score 1	Score 2	Moderate Risk
7	SANSKRUTI	62	Score 1	Score 1	Score 1	Score 2	Score 2	Moderate Risk
8	SWEETY	45	Score 2	Score 1	Score 2	Score 1	Score 2	Moderate Risk
9	PIYALI	40	Score 2	Score 1	Score 1	Score 3	Score 3	High Risk
10	SHAILESH	58	Score 1	Score 2	Score 1	Score 3	Score 3	High Risk
11	SAHIL	46	Score 1	Score 1	Score 2	Score 3	Score 3	High Risk
12	ROHAN	53	Score 1	Score 1	Score 3	Score 2	Score 3	High Risk
13	PRITI	71	Score 1	Score 1	Score 3	Score 3	Score 2	High Risk
14	MANYAA	51	Score 2	Score 3	Score 3	Score 1	Score 1	High Risk
15	RANYAA	49	Score 3	Score 2	Score 3	Score 1	Score 1	High Risk

Table 8: Tested values of Patients

VI. Conclusion:

The goal of this paper is design of a fuzzy expert system for the risk identification of cirrhosis using Child Pugh score. Using this system the need of the liver biopsy can be avoided. The use of the fuzzy logic in the design of the system enhances the reasoning even in case of imprecise data. Combination of fuzzy logic and expert system increases the system performance .

However since there no such thing that has 100% accuracy in any probabilistic estimate outcome model, it is prudent to say, that these scoring system should always go hand in hand with critical clinical analysis and good decision making.

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