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The Evaluation of Liver Function via Grey Relational Analysis

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***Abstract*—Liver diseases and liver cancer has been the top ten causes of death among ten leading causes of death in Taiwan and always in the top. Usually, in the general liver function examination, biochemical test is the most common and a test that show the most direct reflection of the body condition. The health subject can determine the further inspection according to the inspection results. Nevertheless, the result of biochemical tests is not absolute, nor is the results represent in the normal range will not be suffering from liver disease. Therefore, how to let the health subject understand his/her own health condition is the main purpose of this paper. So, this paper makes use of grey relational analysis method and according to the standard values of hospital test results to be divided into Level method and compare with the health subject's test results. It will convert the past ordinal decision into cardinal quantitative evaluation value and evaluate liver function's level. At the same time, it develops MATLAB GUI toolbox to assist the numerical calculation, which can complete a medical assistance platform for liver function evaluation. It not only provides a further step of making decision for doctors in order to promote medical quality, but also provides a new research direction of this field.**

***Keywords*-liver disease and liver cancer, biochemical tests, grey relational analysis, cardinal, MATLAB. liver function evaluation**

I. INTRODUCTION

According to the publicized information by the Department of Health, Taiwan, chronic liver disease and cirrhosis were seventh in the national causes of death[1], liver cancer accounts for the second cause of death, which gives prevention of liver disease a certain degree of attention in Taiwan's health care. The most common liver function test in Taiwan is the biochemical examination, of which, hospitals in general mostly focus on the two main items of AST and ALT, however, according to the statistics from the Department of Health showed that, normal AST and ALT values do not necessary indicate an absence of liver disease and a normal liver function. Since AST and ALT are among the enzymes secreted by hepatic cells, when the cells have injury or necrosis, the AST and ALT within the hepatic cells will be released into the blood, and during which the AST and ALT testing would have a marked increase in value, which can be used to determine whether there is inflammation of the liver, but AST is a sensitive but non-specific indicator for the risk of hepatic cells. A small amount of ALT is stored in the heart, muscles, and other tissues. In the detection of liver function, ALT has higher specificity than AST, however, the higher AST and ALT values, does not necessarily indicate a more serious disease condition. In contrast, if AST and ALT values are normal, this does not necessarily represent that the liver function is normal or there is no liver disease. And γ-GTP is an enzyme that breaks down protein, mainly exists in the liver and bile duct epithelial cells, small amount in kidney, pancreas, brain and other tissues, it belongs to biliary enzymes and is commonly used in the diagnosis of obstruction of the biliary tract or bile acid obstructive liver disease. Apart from that the γ-GTP value is associated with the level of alcohol; the use of certain drugs will also alleviate the value of γ-GTP. As shown in the above description, the relationship between the factors of liver function assessment remains grey. Based on this, this paper proposed the use of grey relational grade in grey system theory to analyze the characteristics and to propose guidelines for liver function assessment.

In past research many have investigated this area[2~5], but only analyzed the liver function index, which were to detect the values of AST, ALT and γ-GTP in blood for the diagnosis of virus infection and liver injury. Apart from these three enzymes, the other test items do not have biochemical standards for diagnosis of liver function, although they could roughly provide an index of liver function, and reflect the liver's state of health. Also there was only one article discussed about quantitative analysis[6], although only a simple analysis, for all the people of Taiwan, no accurate medical

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information of the liver function is provided. Therefore, this paper begins from the perspective of the examined person, with the purpose of quantitative analysis, to apply the values of the grey relational analysis, as a way to classify the liver function, and then proceed with decision-making on the results, and propose warnings and suggestions[7].

Section two of this paper states the grey relational grade. Section three indicates the impact factors of liver function and develop Matlab toolbox to actually calculate the data value for the feasibility of the software. Section four reaches a conclusion for the process and indicates major contributions and suggestions for further development.

II. THE GREY RELATIONAL GRADE

The grey relational grade is the most important topic grey relational analysis, and the main function is the measurement between two discrete sequences[7].

Assume the sequences $x_i(x_i(1),x_i(2),\cdots,x_i(k)) \in X$, where $i = 0,1,2,\cdots,m$, $k = 1,2,3,\cdots,n \in N$, means

$$\begin{aligned} x_0 &= (x_0(1),x_0(2),\cdots,x_0(k)) \\ x_1 &= (x_1(1),x_1(2),\cdots,x_1(k)) \\ x_2 &= (x_2(1),x_2(2),\cdots,x_2(k)) \\ &\vdots \\ x_m &= (x_m(1),x_m(2),\cdots,x_m(k)) \end{aligned} \quad (1)$$

If the $x_0(k)$ is the reference sequence, and the others are inspected sequences, then, it is called the localization grey relational grade(LGRG). If each sequence $x_i(k)$ can be the reference sequence, then, it is called globalization grey relational grade(GGRG), according to the past reference, meantime, there have six kinds of grey relational grades, which are Deng's, Wong's, Wu's, Wen's, Hsia's and Nagai's six methods [7].

Because in the traditional system, there only have one standard sequence, but in our research, there are many corresponding standard sequences. Hence, we adapt Wu, Wen and Hasi methods as our mathematical method, and transfer the grey relational grade into "health alarm signal" for decision-making.

The mathematical models are shown from equation (2) to equation (4).

$$\Gamma_{0i} = \Gamma(x_0,x_i) = \frac{\Delta_{\min.} + \Delta_{\max.}}{\overline{\Delta}_{oi} + \Delta_{\max.}} \ , \ \overline{\Delta}_{0i} = \sqrt{\frac{1}{n}\sum_{k=1}^{n}[\Delta_{oi}(k)]^2} \quad (2)$$

$$\Gamma_{0i} = \Gamma(x_0,x_i) = \frac{\Delta_{\min.} + \Delta_{\max.}}{\overline{\Delta}_{oi} + \Delta_{\max.}}, \ \overline{\Delta}_{0i} = \left\{\frac{1}{n}\sum_{k=1}^{n}[\Delta_{0i}(k)]\right\} \quad (3)$$

$$\Gamma_{0i} = \Gamma(x_0,x_i) = \frac{\Delta_{\max.} - \overline{\Delta}_{0i}}{\Delta_{\max.} - \Delta_{\min.}}, \ \overline{\Delta}_{0i} = \left\{\frac{1}{n}\sum_{k=1}^{n}\Delta_{0i}(k)\right\} \quad (4)$$

III. REAL CASE

A. The liver function influence factor

In Taiwan, There are 12 liver function indicators in the current liver function analysis, all are listed bellow[8].

- The Alanine Aminotransferase: (AST)
- The Aspartate Aminotransferase: (ALT)
- The Total Protein: (T-Protein)
- The Albumin: (Albumin)
- The Globulin: (Globulin)
- The ratio of Albumin and Globulin: (A/G)
- The Total Bilirubin: (T-Bilirubin)
- The Direct Bilirubin: (D-Bilirubin)
- The Alkaline Phosphataes: (ALK-P)
- The γ Globulin Total Protein: (γ -GTP)
- The Creatine phosphor kinase: (CPK)
- The Lactic dehydrogenase: (LDH)

B. The Choosing of Influence Factor

The past researchers indicated that item 1, item 2, item 4, item 9 and item 10 are the influencing factors of this analysis and the relevant analytical scope is shown in TABLE I[6].

TABLE I. THE ANALYSIS ITEMS OF LIVER FUNCTION

No	Items	Range	Unit
1	anine Aminotransferase: AST	10-35	U/*L*
2	partate Aminotransferas: ALT	5-40	U/*L*
4	e Albumin	3.8-5.3	mg/d*l*
9	kaline Phosphataes: ALK-P	66-220	U/*L*
10	mma Globulin Total Protein: γ -GTP	10-87(Male)	U/*L*
		8-31(Female)	U/*L*

C. Mathematics Analysis

According to the Department of Health, Executive Yuan's data, the original mass collected data of testing subjects were from various hospitals without any age difference. Based on TABLE I to divide the impact factors into four levels, each level's scope is shown in TABLE II.

TABLE II. THE GRADE OF LIVER FUNCTION EXAMINATION FACTOR

Grade	I	II	III	IV
ALT	[10,16.25]	(16.25,22.5]	(22.5,28.75]	(28.75,35]
AST	[5,13.75]	(13.75,22.5]	(22.5,31.25]	(31.25,40]
Albumin	[5.3,4.925]	(4.925,4.55]	(4.55,4.175]	(4.175,3.8]
ALK-P	[66,104.5]	(104.5,143]	(143,181.5]	(181.5,220)
$\gamma - GT$ (Male)	[10,29.25]	(29.25,48.5]	(48.5,67.75]	(67.75,87)
$\gamma - GT$ (Female)	[8,15.75]	(15.75,23.5]	(23.5,31.25]	(31.25,39)

* AST and ALT: minimum the batter, ** Albumin: maximum the better, ALK-P and γ -GTP: minimum the batter,

[ ]: Mean in closed interval. ( ): Mean in open interval

D. Steps in The Mathematics Analysis

According to TABLE II, first of all, x_i acts as the testing subject and the classification scope is indicated as four standard sequences from x_I to x_{IV} (for male).

Grade I: X_I =(10,5, 5.3, 66, 10)

Grade II: X_{II} =(16.25, 13.75, 4.9251, 104.51, 29.25)

Grade III: X_{III} =(22.5, 22.5, 4.55, 143, 48.5)

Grade IV: X_{IV} =(28.75, 31.25, 4.175,181.5, 67.75)

E. Decision-Making

Due to the classification of the paper, it is divided into four levels and in order to do the decision-making analysis, the

definition of absolute weighting is 5, 3, 1 and 0. The relative ordering/weighting are 0.4, 0.3, 0.2 and 0.1. The formula for health-score is obtained as

$$\sum_{\text{all grade}}(\text{absolute weighting})\times(\text{relative ordering-weighting}) \quad (5)$$

where the range are

1) Maximum is $5\times0.4+3\times0.3+1\times0.2+0\times0.1=3.1$

2) Minimum is $5\times0.1+3\times0.2+1\times0.3+0\times0.4=1.4$

Then, according to the maximum and minimum values a health decision-making table is set up by using the equal distance method as shown in TABLE III.

TABLE III. THE DECISION-TABLE

Level	Score range	Suggestion
A (Excellent)	2.71 ~ 3.10	Maintain the good condition
B (Good)	2.21 ~ 2.70	Do routine check
C (Bad)	1.71 ~ 2.20	Do further check
D (Worst)	1.40 ~ 1.70	Go to hospital as soon as possible

F. Actual Data Value Analysis

After research, the analyzed subjects were found to be more than 40 years old. It is planned to take 7 examiners to do the analysis[8].

TABLE IV. T HE TESTING DATA FROM FONG-YUAN HOSPITAL

No.	AST	ALT	Albumin	ALK-P	γ -GTP
1	27	34	3.8	49	51
2	25	20	3.9	57	45
3	22	15	3.8	33	53
4	24	32	4.6	67	42
5	21	19	4.2	41	50
6	23	18	3.9	47	58
7	16	13	4.0	62	69

According to the data value in Table IV, using our method and substituted data into (2), (3) and (4), to find the grey relational grade, and get their health score.

TABLE V. THE RESULTS OF GREY RELATIONAL GRADE FOR 7 TESTING DATA (WU'S METHOD)

NO.	GRADE-I	Grade-II	Grade-III	Grade-IV
1	0.646	0.741	0.816	0.774
2	0.641	0.764	0.871	0.768
3	0.689	0.748	0.742	0.678
4	0.589	0.708	0.871	0.831
5	0.680	0.764	0.778	0.702
6	0.677	0.755	0.799	0.758
7	0.668	0.732	0.785	0.791

TABLE VI. THE RESULTS OF GREY RELATIONAL GRADE FOR 7 TESTING DATA (WENS METHOD)

NO.	GRADE-I	Grade-II	Grade-III	Grade-IV
1	0.698	0.807	0.957	0.875
2	0.698	0.829	0.983	0.805
3	0.801	0.940	0.896	0.768
4	0.636	0.753	0.922	0.867
5	0.764	0.901	0.919	0.777
6	0.759	0.869	0.983	0.844
7	0.765	0.855	0.970	0.904

TABLE VII. THE RESULTS OF GREY RELATIONAL GRADE FOR 7 TESTING DATA (HSIA'S METHOD)

NO.	GRADE-I	Grade-II	Grade-III	Grade-IV
1	0.565	0.760	0.954	0.856
2	0.568	0.793	0.983	0.758
3	0.750	0.936	0.883	0.697
4	0.425	0.670	0.915	0.846
5	0.691	0.890	0.912	0.713
6	0.682	0.850	0.983	0.816
7	0.693	0.831	0.969	0.894

TABLE VIII. THE RESULTS OF SCORE AND LEVEL

No.	Wu		Wen		Hsia	
	Score	Level	Score	Level	Score	Level
1	1.5	D	1.5	D	1.5	D
2	1.5	D	1.8	D	1.8	C
3	2.5	B	2.5	B	2.5	B
4	1.5	D	1.5	D	1.5	D
5	1.8	C	1.8	C	1.8	C
6	1.5	D	1.8	C	1.8	C
7	1.4	D	1.5	D	1.5	D

G. The Development of Toolbox

The toolbox for liver function factors weighting analysis has the following characteristics[9].

- The Toolbox changes the current processing grey rational grade theory, formula and methods into the GUI method. The users can clearly and easily learn the implementation function and obtain the best results.
- The input interface adopts GUI in Matlab and reconciles with Microsoft so that it can input set numbers randomly, and based on the characteristics of Microsoft, the user can easily use this data and offer great help in dealing with examiners and subjects.
- The requirements of the toolbox in this system are Window XP; Screen resolutions at least 1024×768 ; Matlab 2007/a version and Data type: Excel.
- The operation steps

i. Open GGRG-LIVER toolbox

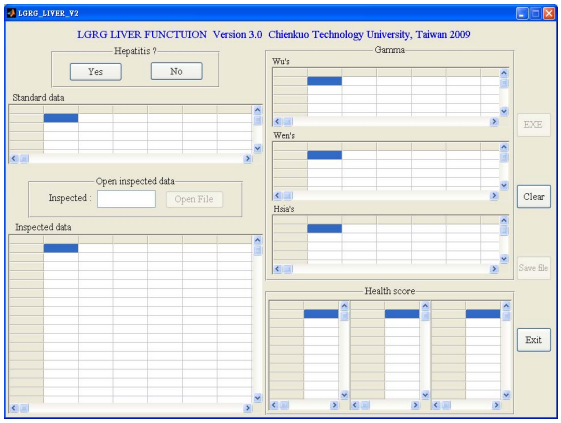

Figure 1. The main screen

ii. Make sure the condition of Hepatitis, if "Yes", then will appera the "Quit" icon, chose "Yes" to leave the toolbox.

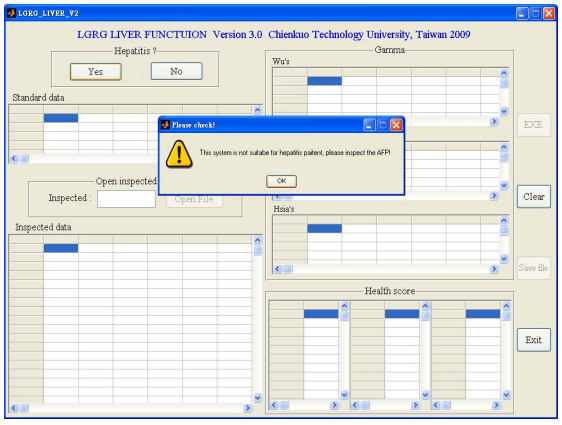

Figure 2. This system is not suitable for hepatitis patent

iii. The results for male patient

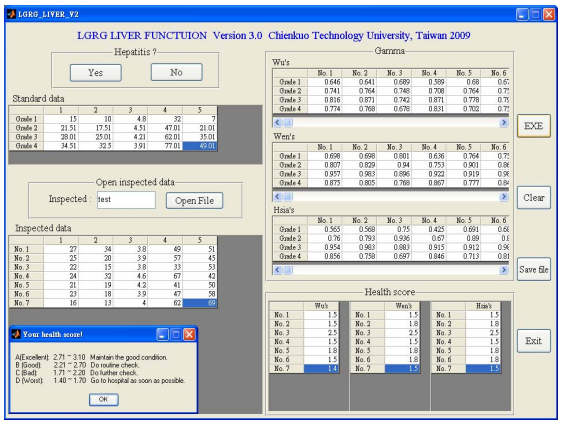

Figure 3. The results for male patient

iv. The results for female patient

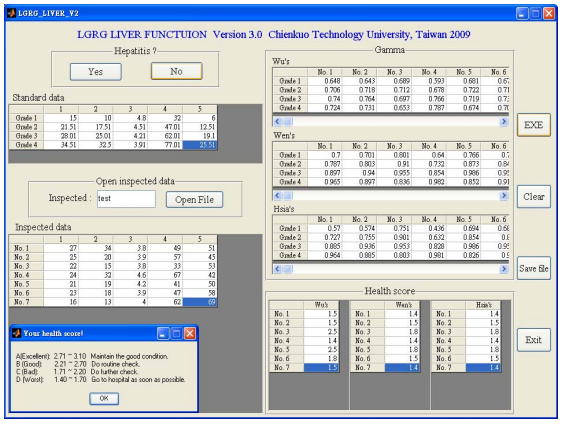

Figure 4. The results for female patient

IV. CONCLUSIONS

In recent years, liver disease and liver cancer remain high as the cause of death in Taiwan. In Taiwan, the liver function testing generally relies on biochemical tests, based on the results, it is difficult for the general public to acquire accurate health information, and differences of the decisions among doctors lead to confusion for the person being examined. Therefore, this paper begins from the perspective of the examined person with the use of the grey relational analysis method, based on the hospital test results into the standard value of classes compared to the test results of the examined person, and developed MATLAB GUI toolbox to facilitate the calculation and analysis of a large number of numerical data. With practical verification, this toolbox developed in this study not only shortens the analysis time, but also increases the speed of the examined person and the doctor's decision time; in addition, this toolbox is able to simultaneously analysis the results from multiple examined persons, also have the functions to analyze both men and women, and results and analytical process storage, and even provide doctors to make further decisions. As Taiwan's current medical network is not well established, data is difficult to obtain, therefore this paper could only use 5 of the 12 test items as the analysis factors. In addition, it was fairly subjective when assessing the weighting of the classes. Hence, in the follow-up study, in addition to including the other factors, which may affect the determination of liver function to achieve a complete and professional quality of medical care, it is recommended to obtain objective data for the assessment of the classification weighting. The combination with other soft computing theories, such as fuzzy theory and rough set theory etc, should also be studied further in the future.

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