ORIGINAL PAPER

AUTOMATIC SYSTEM FOR ANALYSIS OF METABOLIC DISEASE*

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Abstract. *Echography science plays an important role in medicine and life sciences. Echography analysis is a modern technique, effective and non-invasive, widely used in diagnosis and medical investigation. The steatosis (fatty) liver disease is an example of the investigation based on ultrasound imaging examination. Fatty liver disease is a large accumulation of the fat in liver cells. Physicians diagnose the fatty liver disease based on visual and analytical interpretation of the ultrasound imaging. In this study, we intended to distinguish and make a classification between the two pathologies: normal liver and steatosis liver using as decision parameter the Euler number. For the purpose of helping physicians in providing rapid and accurate diagnosis we present a software application for computer-aided ultrasound diagnosis of steatosis diseases. Finally, the authors conclude on the effectiveness of the tested method.*

Keywords: *echography, steatosis liver, Euler number.*

1. INTRODUCTION

Hepatic steatosis is one of the most common liver diseases. This is manifested by an excessive deposition of triglycerides in liver cells. The disease is specific especially to obese people. Steatohepatitis was found in 18.5% of markedly obese patients and 2.7% of lean patients [1]. The affection is reversible and can be treated by a healthy life style. In this study we analyzed two sets of images: a set composed by five images corresponding to healthy liver and another set composed by five images corresponding to steatosis liver. We tried to discriminate between the two pathologies investigated on the basis of Euler's number. The Euler number can be successfully used to describe the topological structure of images [2]. This paper describes a theoretical approach and presents the obtained experimental data and the conclusions of this study.

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2. EXPERIMENTAL

2.1. MATERIALS AND METHOD

The ultrasound (US) images of the human organs obtained by ultrasound devices are digital color images characterized by three trichromatic components: red (R), green (G) and blue (B). In this study we prefer to work with grayscale (atonal) images. For this purpose we convert the RGB values to grayscale values by forming a weighted sum of the red, green, and blue components. The color image characterized by a 3D matrix is transformed into a gray image characterized by a 2D matrix. The relationship that underlies the conversion is:

$$0.2989 * R + 0.5870 * G + 0.1140 * B \tag{1}$$

The image binarization is the process where the number of gray levels of the image is reduced at two (0=black and 255=white) or (0=black and 1=white). The binarization of the images is a thresholding technique. The binarization algorithm consists in choosing a threshold value T and settings with values lower than T to 0 and respectively all pixels with higher values than T to 255. In order to automatic determine the threshold values we can use the Otsu method which is based on the idea of maximizing the variance between two classes [3,4].

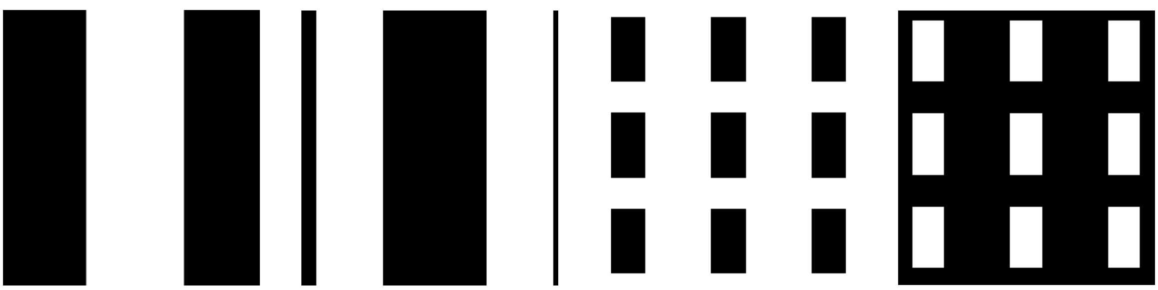
Euler number is a parameter that characterizes the topology of an image. The Euler number is defined as the difference between the number *C* of connected components in an image and the number *H* of holes in those images [5-9].

$$E = C - H \tag{2}$$

Using the Matlab software, the function that returns the Euler number for the binary image BW is:

$$E = bweuler(BW, n) \tag{3}$$

As the tutorial of software programs presents, the argument *n* can have a value of either 4 or 8, where 4 specifies 4-connected objects and 8 specifies 8-connected objects; if the argument is omitted, it defaults to 8. An example to evaluate the Euler's number values of 1, 2, -8 and 9 is presented in Fig.1 (a-d).

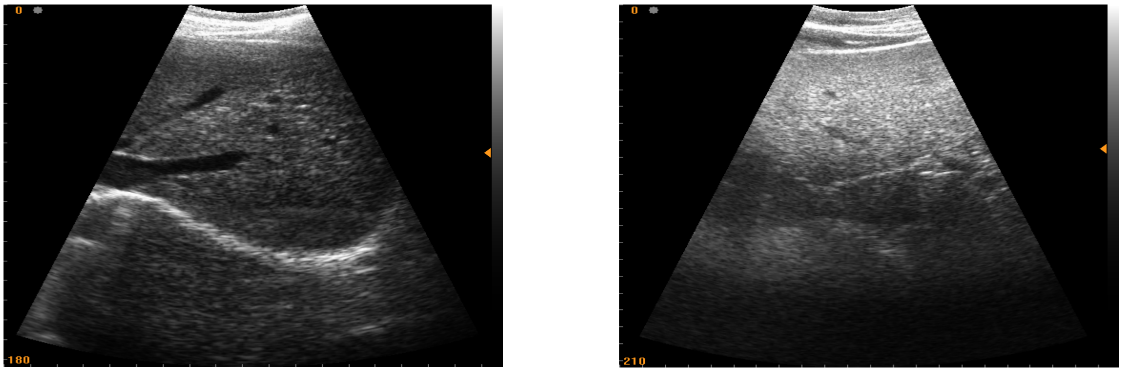


(a) **Euler number = 1.** **(b)** **Euler number = 2.** **(c)** **Euler number = -8.** **(d)** **Euler number = 9.**

Fig. 1. Euler number values.

3. RESULTS AND DISCUSSION

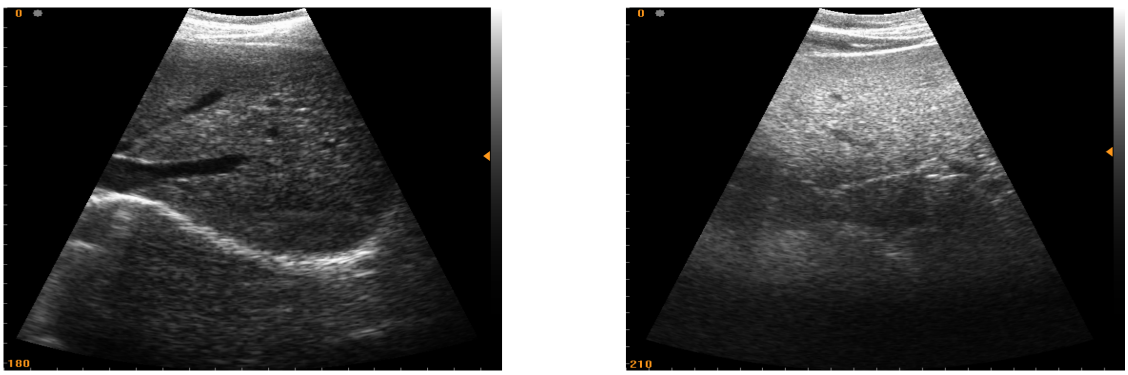
In this study two sets of ultrasound images were analyzed: a set composed of normal liver images and another composed of steatosis liver images. These ultrasound images were acquired using the SLE 401 device ultrasound and processed with MATLAB R2009a. The image parameters are: bitmap images, size 524x512 pixels, 8 bit/pixel. In Fig. 2 (a) and (b) we present examples of the investigated images.



(a) **(b)**

Fig. 2. (a) Normal liver; (b) Steatosis liver.

Our goal was to highlight the accumulation of fat in liver cells corresponding to steatosis liver. Therefore the images were binarizated using a convenient threshold. Exploratory visual analysis of the obtained images at various binarization thresholds allows us to determine the optimal threshold correspond to value 0.6. When a lower threshold (<0.6) has been used, both healthy liver cells and fat cells are affected by white binarization. On the other hand, if a threshold bigger than 0.6 is used then the results consist in the elimination of fats points from steatosis images. The Fig. 3 (a) and (b) present the images from Fig. 2 (a) and (b) binarization to 0.6 value.



(a) **(b)**

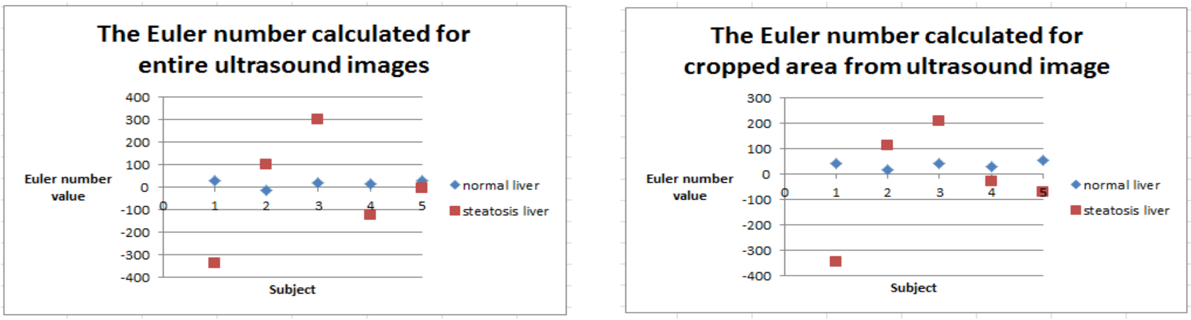
Fig. 3. (a) Normal liver binarization at 0.6 value; (b) Steatosis liver binarization at 0.6 value.

The values of the Euler number for both healthy and fatty liver are calculated. In our analysis there are used the whole images and a convenient area cropped from the image. The obtained results are presented in Table 1.

Table 1. The results of the measured Euler number.

Subject	Euler number of normal liver for entire image	Euler number of steatosis liver for entire image	Euler number of normal liver for cropped image	Euler number of steatosis liver for cropped image
1	28	-339	40	-348
2	-17	99	14	110
3	17	298	41	206
4	15	-123	30	-31
5	29	-7	55	-73

In the Fig. 4 (a, b) are presented the diagrams of Euler's number for all images investigated.



(a) (b)

Fig. 4. The Euler number calculated for (a) entire ultrasound images and (b) for cropped area from ultrasound image.

For the entire ultrasound image, we obtain small absolute values of Euler number for normal liver and high absolute values for steatosis liver. It is noted that the measured parameter values of the subjects for the two pathologies are distributed both in the domain of positive values and the domain of negative values. Also the same findings are obtained in the case of the cropped ultrasound image. It is needed to specify that for normal liver images only positive values are obtained. The large positive Euler number is interpreted objectively due to massive presence of the fat cells (distinct white components). The large negative Euler number specifies many holes (namely normal hepatic cells) interspersed in the areas of the fat cells. The low positive or negative Euler number values can be interpreted by the low percentage or no fat cells in the liver. In this case the number of the holes and the components are close.

The results are affected by the cropping position and the size cropped area. In this study we used the optimal rectangle cropped area of 180, 80, 150, and 100 coordinates. These experimental results can be used as a decision criterion to discriminate between studied pathologies. In order to support the physicians' precise and accurate diagnosis on liver steatosis we developed a CAD software application that could decide between the two pathologies. The criterion of decision is presented in the Fig. 5 and is consistent with the ideas which were the basis of our study.

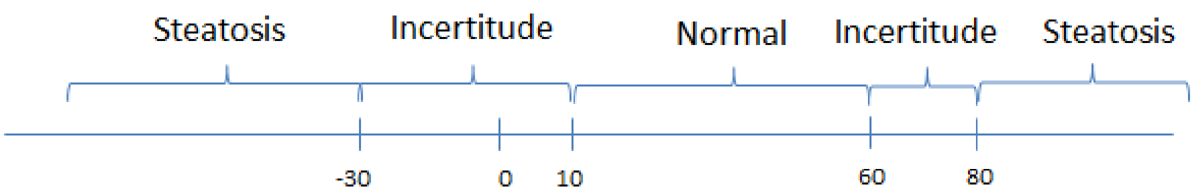


Fig. 5. Criterion decision of CAD software application.

The scheme of the CAD software application is presented in Fig. 6.

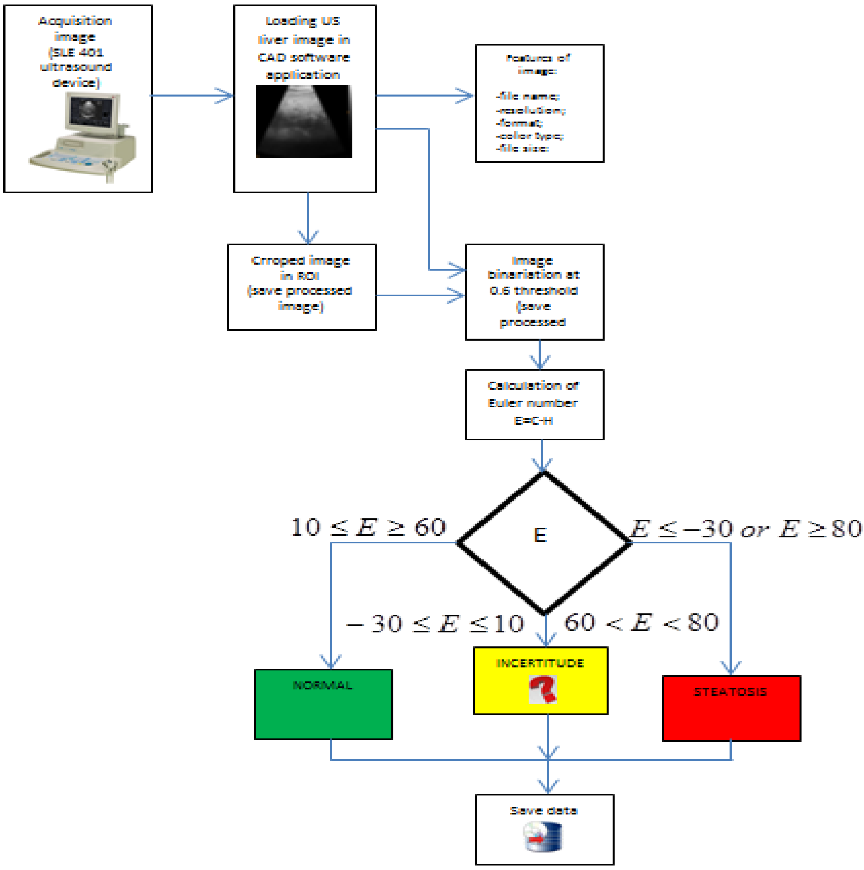


Fig. 6 Scheme of CAD software application.

4. CONCLUSIONS

It is presented an algorithm which allows us to discern between normal and steatosis liver based on the Euler number.

If the value of Euler number is smaller than -30 or higher than 80 the diagnosis is STEATOSIS. If Euler number value is between 10 and 60, the diagnosis is NORMAL. For Euler number values between -30 and 0 and values between 60 and 80 we have a situation of INCERTITUDE. The final diagnosis belongs to a specialist physician.

The obtained results are in agreement to the physicians' opinion about ultrasound images investigated.

In future we intend to extend the ultrasound images database and develop an adaptive learning system based on neuronal networks capable to automatically assess liver pathologies, as presented in this article.

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