Automatic Evaluation of Liver Fibrosis with Chronic Hepatitis C Using Texture Features in Ultrasound Images

Ying Piao † Bunpei Irie † and Kazuaki Tejima ‡
† Toshiba Corporation Power and Industrial Systems R&D Center
‡ Toshiba General Hospital
E-mail: † {ying.piao, bunpei.irie}@toshiba.co.jp, ‡ kazuaki.tejima@toshiba.co.jp

Abstract In this paper an automatic classification algorithm is proposed to evaluate the degree of liver fibrosis using texture features in ultrasound images. Recently, it is proved diagnostic ultrasound is a useful clinical tool for imaging the human soft tissues and some methodologies have been developed in disease diagnosis. However, the most difficult problems of how to remove these small structures from live material, and how to evaluate the degree of liver fibrosis with granularity of texture remain. In this paper, we propose a novel method to resolve these problems. Texture features are used to evaluate the liver fibrosis in ultrasound images in this paper, an algorithm for removing small structures, such as cross section of vessels and capillaries are also proposed. In the experiment, texture features extracted from ultrasound images are examined based on the proposed method, and the resulting values were compared with the fibrosis grades. The results of our study show that the median value of every histogram, which are calculated from fibrosis grade 1 to 4, may be associated with an increase in the grade of liver fibrosis and it is possible to evaluate the degree of liver fibrosis using proposed method by analysis of ultrasound images.

Keyword Texture feature, Liver fibrosis, Ultrasound images, Feature classification

1. Introduction

Liver disease, such as chronic Hepatitis, fatty liver diseases and cirrhosis, is one of the most prevalent diseases. Chronic Hepatitis C is an infectious disease affecting the liver, which is caused by the hepatitis C virus, and has the highest rate about 70% of total liver disease. The infection is often symptomless, but once established, the chronic infection can progress to scarring the liver fibrosis, and advanced scarring cirrhosis which is generally apparent after many years. Thus, an early diagnosis is very important and can help to prevent changing the state of the disease to a developed stage.

Some methodologies have been developed in disease diagnosis [6][7][8][9][10] and some algorithms have been tested on Computed Tomographic(CT) images, which are of higher contrast than ultrasound images[8][10]. But as the ultrasound imaging modality offers the undisputed advantage of being non-invasive, low cost and non-radiological despite low contrast, more research has been initiated in this field. Recently, it is proved diagnostic ultrasound is a useful clinical tool for imaging the human soft tissues [1][4].

S.Poonguzhali et al.[5] proposed a method to build a computer-aided automatic early detection system for the identification of cysts, tumors and cancers by analyzing their unique echo texture patterns using a custom designed back propagation neural network classifier. In their study, the possibilities of an automatic classification of ultrasonic liver images by employing a combined set of statistical and spectral texture parameters are explored. However, this proposed method is only limited in detecting neoplasm, such as cyst, benign and malignant, in ultrasound liver images. Since it is difficult to distinguish between normal liver lesion and chronic hepatitis, the results from this method is obviously too late for early treatment.

On the other hand, Hidenori, Toyoda.[1] proposed a method to evaluate the degree of liver fibrosis in patients with chronic hepatitis C. In their study, the homogeneity of the tissue texture of the liver on B-mode ultrasound images is analyzed on the basis of the result of a statistical chi-square test of the echo amplitudes. However, F1, F2 and F3 groups are poorly demarcated; furthermore, they failed with discrimination between grades F0 and F1.

The most difficult problems of how to remove these small structures, such as vessels and capillaries, from live material, and how to evaluate the degree of liver fibrosis with granularity of texture are remained. In this paper, we propose a novel method to resolve these problems. Texture features will be used to evaluate the liver fibrosis's grades in ultrasound images. An algorithm for removing small structures, such as cross section of vessels and capillaries will be also proposed.

The main contributions of this paper are summarized below:

- A texture feature with rotational invariance based on HLAC is proposed in this study.

- A method to remove non-liver tissue in ultrasound images is proposed.
- We evaluate the efficacy of proposed method with some ultrasound liver images, which are collected from hospital on various patients with chronic hepatitis C.

This paper is organized as follows. Chapter 2 explains feature extraction. Chapter 3 describes the proposed algorithm to evaluate the degree of liver fibrosis. Materials and evaluation will be described in chapter 4. Finally the application of this method and its effectiveness to classify liver ultrasound tissue will be shown.

2. Feature extraction

Since liver is an organ with many structures such as vessels and capillaries, these parts of non-liver tissues are included in ultrasound Images. Since the purpose of this study is to evaluate the degree of liver fibrosis with chronic hepatitis C in ultrasound images, it is necessary to remove these non-liver tissue parts as preprocess.

In this chapter, two texture feature extraction methods will be described for liver material texture granularity classification and non-liver tissue texture extraction. Firstly, an improved feature extracting method which is based on HLAC (Higher order local autocorrelation) will be explained. Secondly, we will propose a texture feature extraction method to remove non-liver tissues, such as cross section of vessels and capillaries.

2.1 Rotational Invariance Feature based on HLAC

HLAC is an effective method for extracting the texture features[2][3] and can be used for wide applications such as motion recognition, face detection and others. HLAC features are primitive image features in Eq.(1) based on higher-order statistics. The Nth order autocorrelation functions are defined as

$$H_r(a_1, a_2, ..., a_N) = \int f(r)f(r + a_1)f(r + a_2)dr, \quad (1)$$

where $f(r)$ denotes the intensity at the observing pixel r and $a_1, a_2, ..., a_N$ are N displacement neighborhoods of r.

The original HLAC features can be restricted up to the second order and within a displacement region. Binary image can be represented by 25 mask patterns with 0, 1 and 2 displacements as shown in Fig.1, and gray image can be represented by 35 mask patterns.

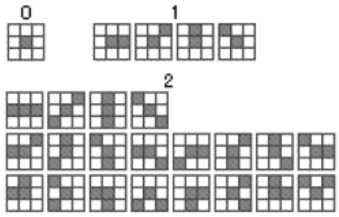


Fig.1. 25 mask patterns of the 0th- order to 2nd-order HLAC features(3×3 pixels)

Thus, Eq.(1) can be calculated as Eq.(2), Eq.(3) and Eq.(4) with 0, 1 and 2 displacements respectively.

$$H_r = f(r) \quad (2)$$

$$H_r(a_1) = f(r)f(r + a_1) \quad (3)$$

$$H_r(a_1, a_2) = f(r)f(r + a_1)f(r + a_2) \quad (4)$$

Each pixel can be considered as a rotation center, which seems to be the convention in deriving rotation invariant operators. The rotation invariant HLAC can be defined as follows.

When a gray image is rotated, the gray values of one pixel in a circular neighbor set move along the perimeter of a circle center. For removing the effect of rotation, 35 mask patterns can be combined as 9 groups as shown in Fig.2.

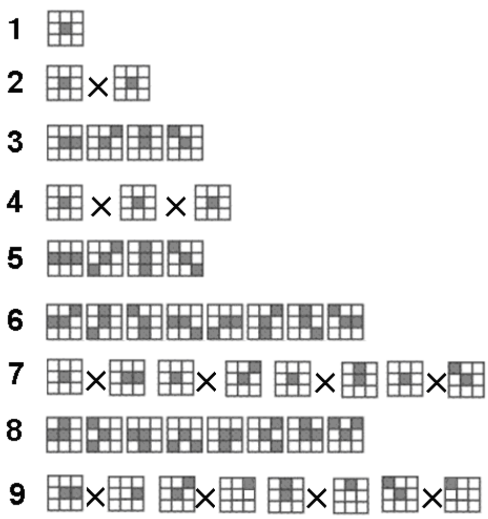


Fig.2. Extended rotational invariance feature based on original HLAC.

For example, these 4 mask patterns on third row of Fig.2 can be united as one mask pattern with a 45° rotation around the center point. Thus, the texture feature can be calculated by using the mean of four features that were extracted from these four patterns.

The Nth order autocorrelation functions calculated from each group can be rewritten as Eq.(5)

$$x(a_k) = \frac{1}{M}\sum_{j=1}^{M} x(a_N), \tag{5}$$

here, M is the number of different patterns included in the same group; k is the group number and $a_1, a_2, ..., a_N$ are N displacements. Thus, with the proposed method, the original HLAC can be extended to a rotational invariance in extracting texture features. Since it is possible for us to calculate a 9-dimensional feature vector instead of 35-dimensional ones, the proposed method causes a large reduction in calculation cost too.

2.2 Non-liver tissue Feature

An example of ultrasound liver image is shown in Fig.3. Texture features extracted from liver tissues, vessels and capillary vessels are different from each other. Here, we propose a method to remove these non-liver tissues from ultrasound images.

Let regions of interest Images are represented by P , and a rectangular region in image is denoted with R; $R \subset P$.

Texture features extracted from plane R can be represented by $f_n(\sigma, \mu)$,

$$f_n(\sigma) = \sqrt{\frac{1}{N}\sum_{i=1}^{N} [(x_i - f_n(\mu))^2]}, \tag{6}$$

where,

$$f_n(\mu) = \frac{1}{N}\sum_{i=1}^{N} x_i , \tag{7}$$

here, x is the grey level of a pixel in gray ultrasound image, $f(\mu)$ is the mean of all x in rectangular region of R ; $f(\sigma)$ is the standard deviation of the mean, and n is the number of R in the regions of interest Image P .

Then, we can calculate the feature vectors from regions of interest Image P by using Eq.(8)

$$F = [f_1(\sigma, \mu) f_2(\sigma, \mu) ... f_n(\sigma, \mu)]^T . \tag{8}$$

Since the texture features extracted from vessels hold the deviation from normal liver tissues, by using these features based on grey level, it is possible for us to remove these non-liver tissues. The results will be shown in chapter 4 with some ultrasound images.

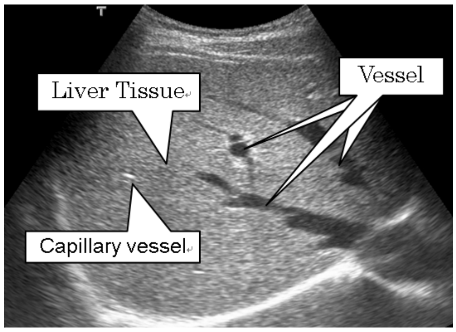


Fig.3. An example of liver ultrasound image

3. Algorithm of Liver fibrosis evaluation

We will describe the algorithm of liver fibrosis evaluation as follows:

Step 1: Input the ultrasound liver images. Since we will remove these parts which are deviated from the most part, the liver tissue part should cover most parts of the region of interest image.

Step 2: Extract texture feature for distinguishing the normal liver tissue from others. The feature described in sention2.2 will be used at this step.

Step 3: Remove non-liver tissues. By using the texture features extracted at step2, it is possible for us to remove these non-liver tissue deviated from normal liver tissue.

Step 4: Extract texture feature to evaluate the degree of liver fibrosis. We will extract texture feature by using the proposed 9-dimensional HLAC to evaluate the liver tissue.

Step5: Evaluate the degree of liver fibrosis. At this step, the value of separation degree between different fibrosis grades is used to evaluate the proposed method with others.

4. Materials and evaluation

In this study, the gray scale ultrasound liver images are collected from TOSHIBA hospital on various patients with chronic hepatitis C under similar imaging conditions. Total twenty-nine images for test are histopathologically tested and have been confirmed by the radiologists to 4 grades from 1 to 4 as shown in Table 1.

Table.1. Characteristics of study images

Fibrasis grade	1 (−)	2 (+−)	3 (+)	4 (++)
HCV	7	8	7	7

The results, which are calculated by using the proposed method compared with the radiologists' diagnosis and evaluated with degree of separation, are shown below.

Degree of separation can be calculated by using between-class variance and within-class variance as follow:

$$\sigma(w,t) = \frac{\sigma_b^2}{\sigma_w^2}, \quad (9)$$

here, $\sigma(w,t)$ means degree of separation, σ_b is between-class variance, and σ_w is within-class variance. σ_b and σ_w can be defined as Eq.(9) and Eq.(10)

$$\sigma_b^2 = \frac{\omega_1\omega_2(m_1 - m_2)^2}{(\omega_1 + \omega_2)^2} \quad (10)$$

$$\sigma_w^2 = \frac{\omega_1\sigma_1^2 + \omega_2\sigma_2^2}{\omega_1 + \omega_2} \quad (11)$$

ω_1 is the number of samples in group1, and ω_2 is the number of samples in group2. m is the mean and σ is the distribution of all feature values in each group.

5. Experiments

The difference between the proposed method and others are shown by using some experiments.

5.1 Texture Comparison

First, we will compare the texture features extracted by using the original HLAC with extended HLAC.

Firstly, we extract original 35-dimensional HLAC feature vector from each rectangular region (3×3 pixels) from region of interest images. By combining 35-dimensional feature vector, it is possible for us to get a scalar feature from each rectangular region. The mean values of 35-dimensional features are employed in texture analysis as final texture features. Secondly, we calculate the average feature from each rectangular region and calculate the distribution by using the average feature from each region of interest images. And then thirdly, we calculate the feature, which is based on 35-dimensional HLAC feature vector, from each image.

This calculation will be repeated by using the proposed 9-dimensional HLAC feature vector. The results compared with these two methods as shown in Fig.4 and Fig.5.

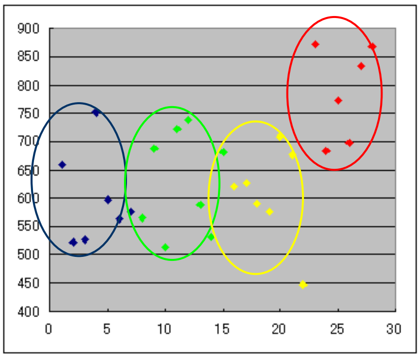


Fig.4. Feature values calculated from ultrasound images by using original 35-dimensional HLAC. Four degrees of liver fibrosis are represented with different colors. The blue points are features which are calculated from these images confirmed by the radiologists of grade 1, green points from these images of grade 2, yellow points from these images of grade 3and red points from these images of grade 4.

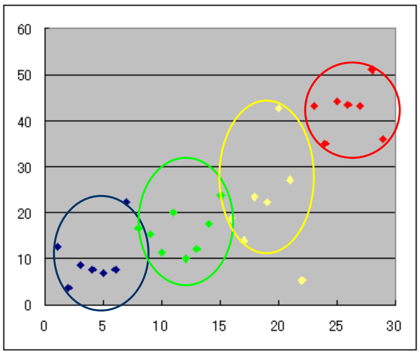


Fig.5. Feature values calculated from ultrasound images by using proposed 9-dimensional HLAC

Fig.4 shows the result computed from 35-dimensional HLAC feature vector, the horizontal axis is image number and the vertical axis is the feature value. As shown in Fig.4, four degrees of liver fibrosis are represented with different colors. The blue points are features which are calculated from these images confirmed by the radiologists of grade 1, green points from these images of grade 2, yellow points from these images of grade 3and red points from these images of grade 4.

On the other hand, the features computed by using the proposed 9-dimensional HLAC feature vector are shown in Fig.5. Compare Fig.4 with Fig.5, it is clearly the classification has greatly improved.

The table 2 compares the values of separation degrees which are calculated by using the original 35-dimensional HLAC method and the proposed 9-dimensional HLAC method. As shown in this table, there is a large difference between these two methods in the degree of separation and it is clear that our method improved the efficiency.

Table.2. Degrees of separation calculated from each fibrosis grade by using the original HLAC and proposed HLAC.

	Degree of separation	
	Calculated from Proposed HLAC	Calculated from original HLAC
grade1:grade2	0.007	0.001
grade2:grade3	0.006	0.000
grade3:grade4	0.030	0.034
grade1,2,3:grade4	0.007	0.003

5.2 Remove non-liver tissue

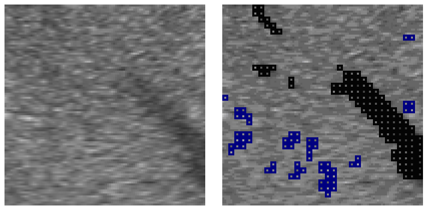
In this section, we will show the results of some experiments to remove non-liver tissue by using texture feature. As described in section 2.1, the texture features extracted from normal liver tissues are different from others. In ultrasound images, the grey lever of soft tissues, such as blood, is low and the grey lever of hard tissue is high. Thus, texture feature of blood vessel is dark and smooth, on the other hand, capillary vessel and vessel wall are bright and rough. Thus, these non-liver tissue parts can be removed by using texture features which are described in section 2.2. Some results of removing small structures, such as cross section of vessels and capillaries vessels which are discriminated by using the proposed method as shown in fig.6. (a), (b), (c) and (d).

In Fig.6, the images on left are original images and the images after processing are shown on right.

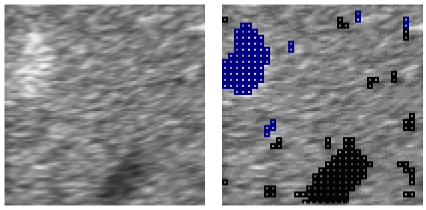
Here, these black parts are blood vessels and blues are capillary vessels and vessel walls. As shown in these images, by using the proposed method, most parts of non-liver tissues can be removed successfully.

Next, we will compare the texture classification before and after non-liver tissue removed. Fig.7 shows the results of extracted texture features, which are calculated from ultrasound images by using proposed 9-dimensional HLAC after removing these non-liver tissues. Table.3 shows degrees of separation computed from the images after removing these non-liver tissues. As shown in these results, the degrees of separations are improved greatly after removing these parts such as vessels and capillary vessels.

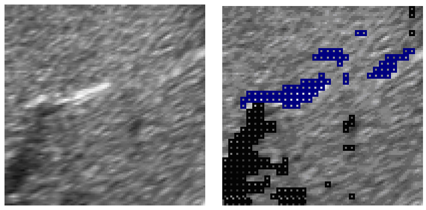
Fig.8. shows median values with range in histogram according to stage of chronic hepatitis. The results of our study show that the median value of every histogram, from fibrosis grade 1 to 4, may be associated with an increase in the grade of liver fibrosis. The value of grade 4 is higher than others (grade 1,2 and 3). The median value of each group gradually increased with an increase in liver fibrosis grade.



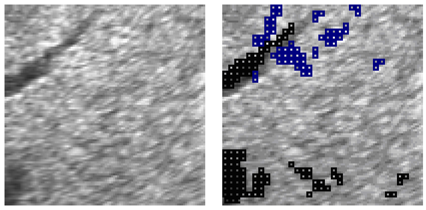
(a)



(b)



(c)



(d)

Fig.6. Some results of remove small structures, such as cross section of vessels and capillaries vessels by using the proposed method.

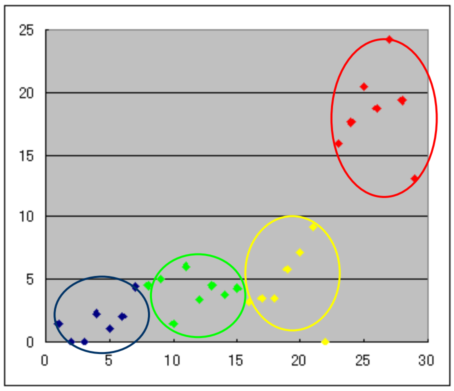


Fig.7. Feature values calculated from ultrasound images by using proposed 9-dimensional HLAC after remove these non-liver tissues.

Thus, it is possible to evaluate the degree of liver fibrosis using proposed method by analysis of ultrasound images.

Table.3. Degrees of separation calculated from each fibrosis grade by using the Proposed HLAC after remove non-liver tissues.

	Degree of separation
	Remove non-liver tissue
grade1:grade2	0.020
grade2:grade3	0.000
grade3:grade4	0.123
grade1,2,3:grade4	0.023

6. Discussion and conclusion

In this paper, we proposed a method to evaluate the degree of liver fibrosis using texture feature in ultrasound images. Firstly, we described an improved feature extraction method based on HLAC; secondly, we proposed a method to remove non-liver tissue. We showed some results from liver ultrasound images in some experiments. The results of our study show it is possible to evaluate the degree of liver fibrosis using proposed method by analysis of ultrasound images.

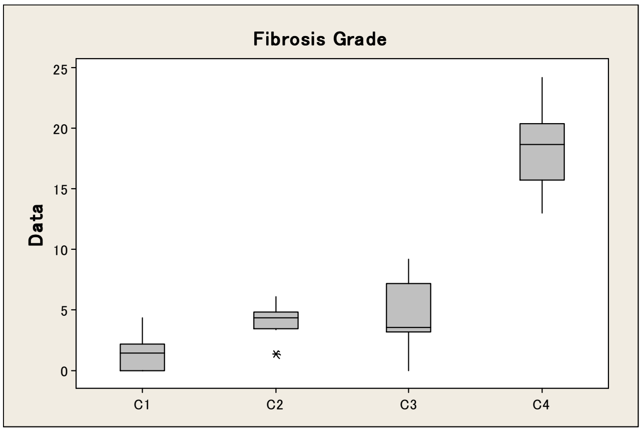


Fig.8. Feature median values with range in histogram according to stage of chronic hepatitis.

From the results, it is shown that the value extracted from fibrosis grade 4 is highest and the value extracted from fibrosis grade 1 is lower than others. The values gradually increased with an increase in liver fibrosis grade, although it is difficult to describe the difference between grade 2 and 3, which should be improved in the future.

References

[1] Hidenori, Toyoda, "B-Mode Ultrasound With Algorithm Based on Statistical Analysis of Signals：Evaluation of Liver Fibrosis in Patients With Chronic Hepatitis C," AJR:193,October 2009

[2] Takahiro Toyoda, Osamu Hasegawa, "Texture Classification Using Extended Higher Order Local Autocorrelation", Procceding of the 4th International workshop on Texture Analysis and synthesis, PP. 131-136,2005.

[3] Nobuyuki Otsu and Takio Kurita, "A New Scheme for Practical Flexible and Intelligent Vision Systems", IAPR Workshop on CV-Special Hardware and Industrial Applications OCT 12-14, 1988.

[4] Ricardo Ribeiro, Jose Seabra and Joao Sanches, "Fatty liver characterization and classification by ultrasound", IbPRIA '09 Proceedings of the 4th Iberian Conference on Pattern Recognition and Image Analysis Springer-Verlag Berlin, Heidelberg, 2009

[5] S.Poonguzhali and G.Ravindran, "Automatic Classification of Focal Lesions in Ultrasound Liver Images Using Combined Texture Features", Information Technology Journal 7(1): 205-209,2008

[6] M.J.Gangeh, R.P.W.Duin, C.Eswaran and B.M.ter Haar Romeny, "Scale Space Texture Classification Using Combined Classifiers with Application to Ultrasound Tissue Characterization", in: F. Ibrahim, N.A. Abu Osman, J. Usman, N.A. Kadri (eds.), International Conference on Biomedical Engineering (11-14 December 2006, Kuala Lumpur, Malaysia), Proceedings IFMBE, vol. 15, 2006, 303-306.

[7] A. Mueen, M. Sapiyan Baba and R. Zainuddin, "Multilevel Feature Extraction and X-ray Image Classification", Journal of Applied Sciences, Volume: 7, Issue: 8, Page No.: 1224-1229, 2007

[8] Chien-Cheng Lee1, Yu-Chun Chiang, Chun-Li Tsai, and Sz-Han Chen, "Distinction of Liver Disease from CT Images Using Kernel-based Classifiers", International Journal of Intelligent Computing in Medical Sciences and Image Processing, Vol. 1, No. 2, Page 113 of 120, 2007,

[9] Raeth U, Schlaps D, Limberg B, Zuna I, Lorenz A, van Kaick G, Lorenz WJ, Kommerell B."""" Diagnostic accuracy of computerized B-scan texture analysis and conventional ultrasonography in diffuse parenchymal and malignant liver disease", J.Clin. Ultra., 13:87-89, 1985

[10] Mougiakakou, S.G.; Valavanis, I.; Nikita, K.S.; Nikita, A.; Kelekis, D.;" Characterization of CT liver lesions based on texture features and a multiple neural network classification scheme", Engineering in Medicine and Biology Society, Proceedings of the 25th Annual International Conference of the IEEE, 2003.