Quantitative Tissue Characterization Program, Computing and Color-Mapping of Ultrasound Parameters for Computerized Diagnosis of Liver Pathologies

Ahmed M. Badawi, Ph.D., Ayman Khalifa, B.Sc., Abou-Bakr M. Youssef, Ph.D.,M.D.
Department of Biomedical Engineering , Faculty of Eng., Cairo University, Egypt

Abstract: In this paper a new quantitative tissue characterization (QTC) program was developed for computing a standardized sets of parameters and quantitative color-mapping of these parameters for non-invasive accurate diagnosis of liver pathologies. In this program, histogram, co-occurrence matrix, runlength matrix, gradient texture feature coding, backscattering, attenuation and speckle parameters were numerically calculated and color mapped in the ultrasound image. The standardization of these parameters using AIUM tissue phantom simulating liver texture, were done for accurate differentiation and estimation of the quantitative parameters. A QTC program was linked to the Neural Net and Fuzzy Logic modules so as to diagnose an unknown liver pathologies. This program is used for quantification and calculation of physical properties of tissues, color mapping of such properties and diagnosis of these tissues. Also it can be extended for real time color mapping of ultrasound parameters with motion.

Keywords: Quantitative Tissue Characterization (QTC), color-mapping of textural and acoustical features of ultrasound images.

1. INTRODUCTION

Conventional grey scale B-mode ultrasound is widely applied and useful diagnostic tool in the management of liver diseases. Nevertheless its operator dependency leading to considerable observer variation, and varying figure for its diagnostic accuracy are well documented in the literature [1]. Visual criteria for diagnosing diffused liver diseases are in general confusing and highly subjective because they depend on the sonographer to observe certain textural characteristics from the image and compare them to those developed for different pathologies to determine the type of the disease. An example for these features is texture

homogeneity. Its presence or absence can be widely debated between different experienced sonographers. Another feature is texture echogenicity which can be a matter of argument in marginal cases. Moreover, some of the diseases are highly similar in their diagnostic criteria, which tend to confuse the sonographers even more.

The Visual criteria provides low diagnostic accuracy (around 70%) [1-2]. Therefore the physicians may have to use further invasive methods such as the pathology investigation of ultrasonically guided needle Biopsy. Although this technique is considered to be the golden test for diagnosis, it has the disadvantage of being invasive and more importantly, it may cause a great risk of cancer spread if it cuts through a localized cancer area [4-7]. Quantitative tissue characterization has been described in the literature using tissue backscattering and attenuation measurements Researchers has used pattern recognition to classify different diffuse liver pathologies [2-7].

2. DATA ACQUISITION

In the DAS system, figure 1 , the video output of a Kretz-320 mechanical sector ultrasound scanner was connected to a Matrox PIP-512 frame grabber card on an IBM-586 PC. The image is captured in 512X512 pixels, the resolution is 8 bits/pixel. A s/w was developed to define the *ROI* and to extract all the forementioned parameters (image analysis) from the acquired B-mode ultrasound images [5].

To obtain a reproducible results, the following parameters were standardized for all tissue characterization parameters [5-7]:

1- Ultrasound machine settings: e.g., *TGC, FOCUS, FREQUENCY,* and *ZOOM* controls, which can change the overall image gain and produce zooming effects and hence deviates the image statistics in an unpredictable way. Moreover, the frequency of ultrasound waves used must be the same since the attenuation is frequency dependent.

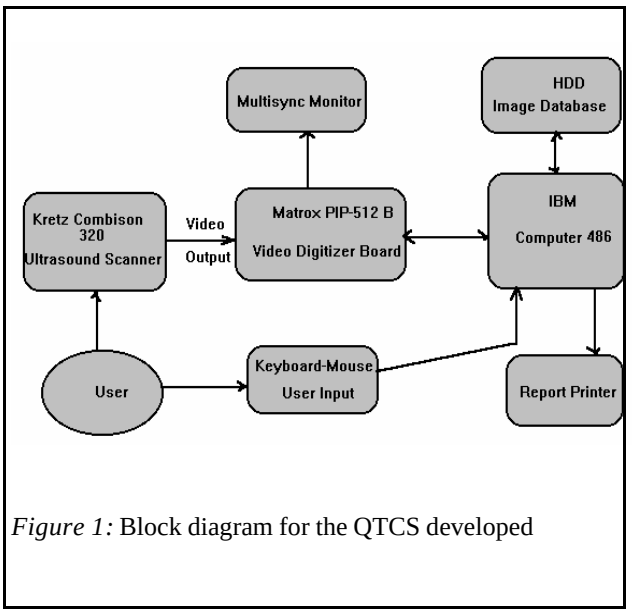

Figure 1: Block diagram for the QTCS developed

2-ROI shape, size and *location:* to obtain a reliable statistics, the number of pixels in the *ROI* must be at least 1000 pixels, the shape should be square. To avoid the distorting effects in an ultrasonic wave patterns such as

side lobes and grating lobes, the *ROI* is selected at the center line of the image, and then corrected for diffraction and focusing of the ultrasound beam.

3. MATERIALS AND METHODS

Towards finding a relation between the sonographers subjective evaluation for the tissue and texture properties of ultrasound images and the quantitative representation for such a properties, the QTCS (quantitative tissue characterization system) program called "LIVERDIAGNOSTICS" was developed to quantify all the properties that the sonographer describe in the image qualitatively and to map such a properties in a selected ROI to show regions of increased and decreased properties as echogenicity, ,coarseness, attenuation or homgeneity.

The visual criteria used by the sonographer for subjective evaluation of liver diseases are:

1. Parenchymal echogenicity and penetration.
2. Peripheral vascular pattern and portal vein fibrosis.
3. Liver and caudate lobe size, ascites, and spleen size.
4. Site, contour, size, and echo pattern of malignant lesions if found.

Due to the low diagnostic accuracy of the subjective evaluation the clinician are forced to do the golden "BIOPSY" test to know the histopathology of the liver.
In our QTC program we quantitatively described the echogenicity, the penetration, and homogeneity with numerical compuerized analysis for the ultrasound images.
We analyzed the standard ultrasound B-scan image for different groups and categories of parameters. Some of these parameters are independent of the depth, size and shape of ROI selected . Some of these parameters are dependent on the spatial distribution of the greyleves in the image and others are not. The categories of parameters are:

1-Histogram parameters:
These are mean gray level (*MGL*, which characterize the echogenicity), gray level variance (*VAR*), signal to noise ratio (*MGL*/*VAR*), skewness (characterize the deviation of the greylevel distribution from a symmetrical reference distribution), curtosis (characterize the steepness of the greylevel distribution) and five of the relevant gray level histogram percentiles [10].

2-Co-occurrence matrix parameters:
These are contrast (*CON, characterize the tissue coarseness*), entropy (*ENT, characterize tissue homogeneity*), correlation (*COR, charcterize a measure of linearity in the relationship of the grey levels of the co-ocurrence matrix*), and angular second moment (*ASM, characterize grey level clustering transition in the co-ocurrence matrix*) [10].

3- First order gradient Parameters:
These are $Absv+_{ave}$, $Absv-_{ave}$, $Absv+_{var}$, $Absv-_{var}$,*Most* Dominant Edge Direction *(MDE)*, Relative frequency of the most dominant edge *(RFMDE)* [10].

4-Greylevel runlength matrix parameters:
It characterize the count distribution of the greylevels in histogram. These are Run percentage(*RPER*), Long-Run emphasis(*LREM*), Greylevel distribution (*GDIST*), Runlength distribution(*RLDIST*) [10].

5-Texture feature descriptors (TFD) parameters:
These Coarseness(coarse), Homogeneity(*HOM*), Mean Convergence(*MC*), Variance(*Var*), Entropy(*Entropy*), Runlength Density(*RLD*), Regularity(*Regularity*),Greylevel Resolution Similarity(*GLRS*) [11].

6-Speckle Parameters:
These are mean scatterer separation (*d*), diffuse and specular scatterer intensity (I_d,I_s), specular standard deviation (s_s) and a few other related parameters [8].

7-Acoustical parameters:
These are attenuation coefficient (*ATTEN a, characterize penetration*) [12] and the backscattering coefficient (*BSC m, characterize backscattered power to the transducer*) [9].

4. RESULTS

Here is an example for some statistics and numerical calculations for properties such as echogenicity (MGL), penetration (ATTEN) and coarseness (CON) in some liver pathologies.

Params.	μ_c	σ_c	μ_n	σ_n
MGL	26.45	5.7	21.2	2.21
VAR	35.3	6.22	18.2	4.1
PER0.9	33.58	6.198	28.3	3.6
B.SC	0.00399	0.00045	0.00341	0.00033
CONT	58.49	16.2	41.3	8.9
ASM	0.00392	0.00137	0.0043	0.00117
ENTR	5.982	0.335	5.647	0.282
CORR	0.095	0.066	0.1022	0.0921
ATTEN	0.531	0.067	0.4721	0.039
d	2.79	0.58	1.9	0.55
Id	53.8	24.11	52.5	22.2
Is	656.6	382.8	504.6	196.2
PIIIP	7.39	1.686	3.47	0.711

Table 1: Statistics for QTC parameters for normal and cirrhosis livers Note, c stands for cirrhosis, and n for normal liver pathologies

The program contains major menus like file(new, open, close, save, save as, print setup, print preview, print, and exit), edit (undo, cut, copy, and paste), view (toolbar and statusbar), region style(ploygon), window (new window, cascade, tile and arrange icons), help (help topic, about

DIAGNOSTICIAN), settings (frequency, and pixel per cm measurements either manually or automatically), parameters (calculation, display, and mapping), diagnosis (diagnosis, using fuzzy logic rules, fuzzy similarity and neural networks, show existing pathologies and appending new case).
The following are some figures and demonstrations for the capability and features in our QTCS program called LIVERDIAGNOSTICS.

Parameters Calculation

If we want to calculate the parameters, we select the region of interest ROI from the image about 5-6 cm. distant from the ultrasound transducer, see figure 2.

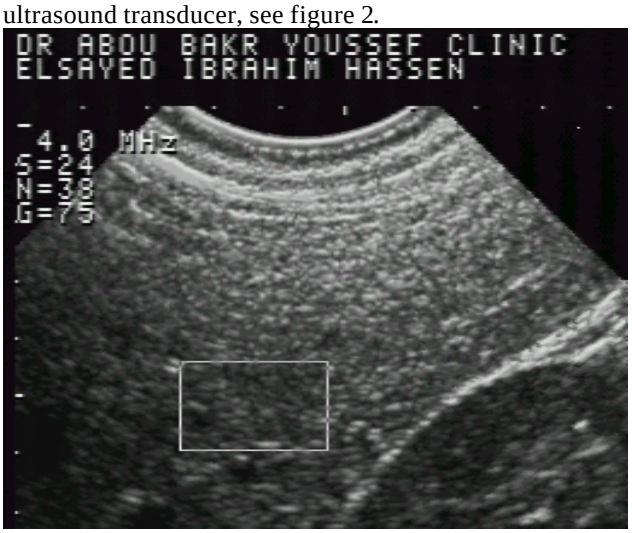

Figure 2: B-mode image for a cirrhotic liver at 4 Mhz

Then a dialogue will appear from which you can select the desired parameters, see figure 3.

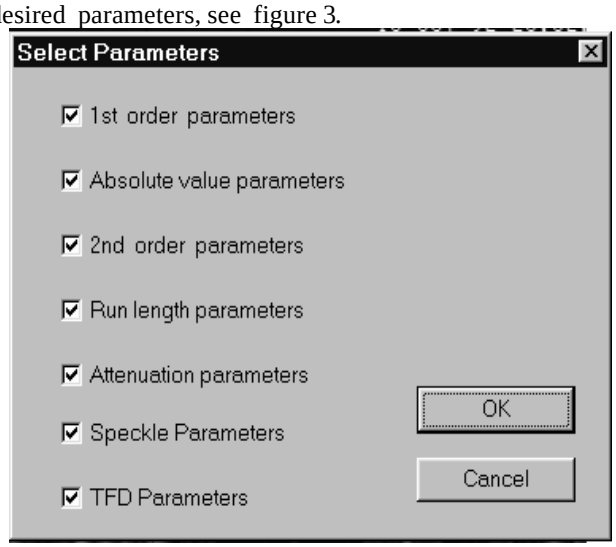

Figure 3: A dialogue to select the desired QTC parameters

After calculating the parameters, we need to display them in a dialogue as in figure 4.

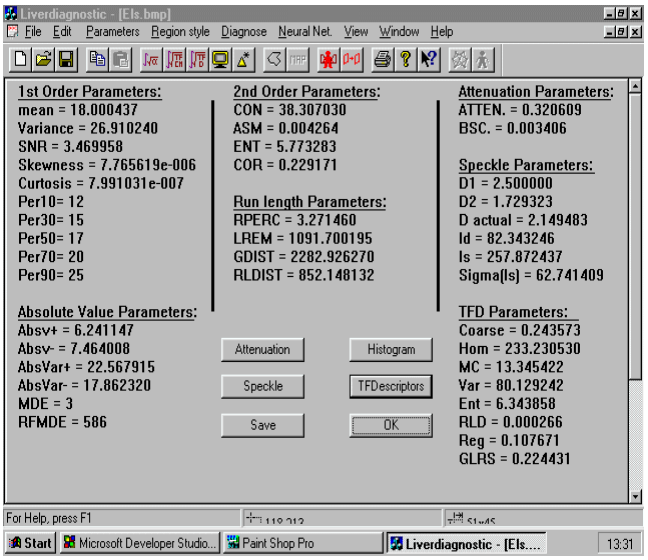

Figure 4: A dialogue to display the QTC parameters

To display the histogram for the ROI, select the histogram button, you will have the histogram Dialogue as in figure 5.

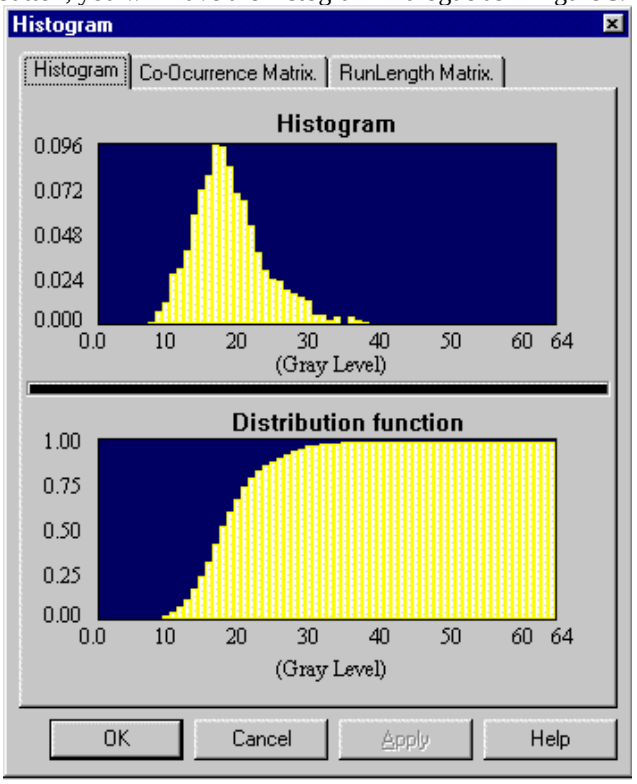

Figure 5: Histogram and distribution function dialogue.

From the Histogram dialogue, you select either Histogram, Co-occurrence Matrix or RunLength Matrix to display, see figures 5,6,7.

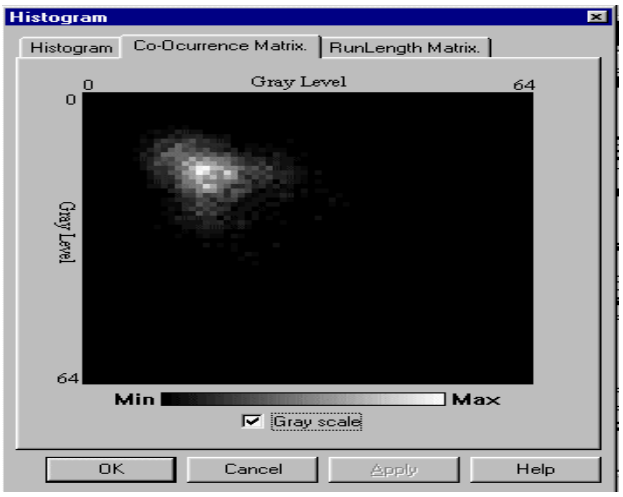

Figure 6: a greyscale display for the co-ocurrence matrix

Figure 7: a greyscale display for the runlength matrix

To display atten. Map for the selected ROI select the atten. Button, see figure 8.

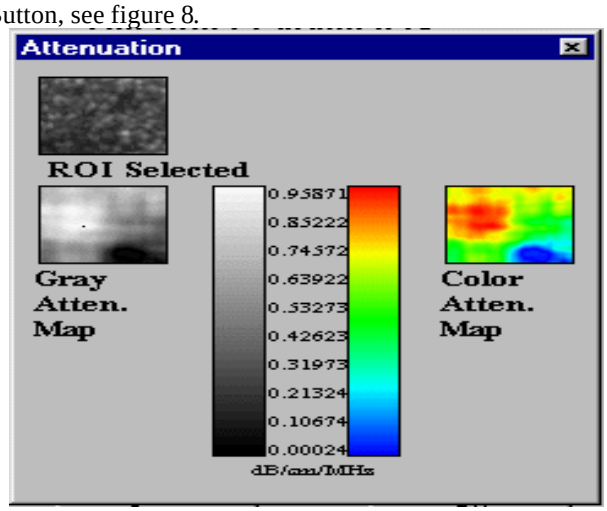

Figure 8: a greyscale and color display for the attenuation.

To display autocorrelation and power spectrum for the selected ROI select the speckle button, see figure 9.

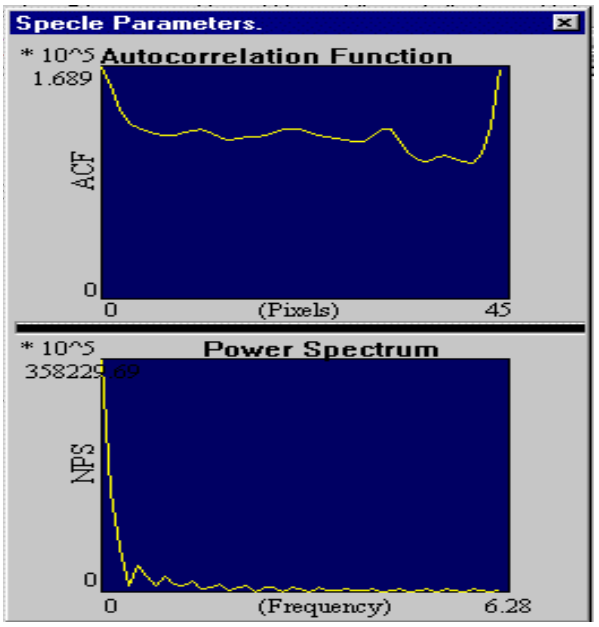

Figure 9: A display for the autocorrelation and power spectrum for the selected ROI.

To display TFD parameters and joint probability matrix you can select TFDescriptors button from the Parameters Dialogue see figure 10.

Figure 10: A display for TFD parameters and joint probability matrix for the selected ROI.

Mapping

To map the parameters into color or greyscale codes, select a polygon region from the image, then select the set of parameters to be coded.

Here is an example for mapping such a parameters (tissue properties) in the B-mode images, where the color or grey scale code for the selected ROI is superimposed on the B-mode grey scale image, see figures 11-19 where a ROI at the kidney is selected and mapped for set of parameters..

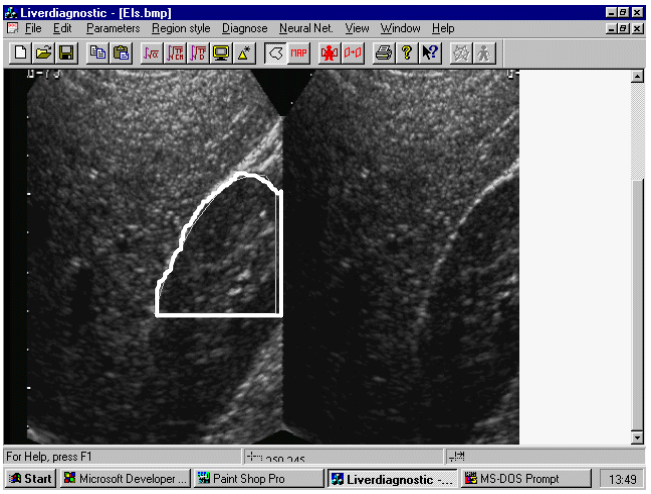

Figure 11: A small polygon ROI in the kidney is selected

A dialogue box will appear from which you can select the required set parameters see figure 12.

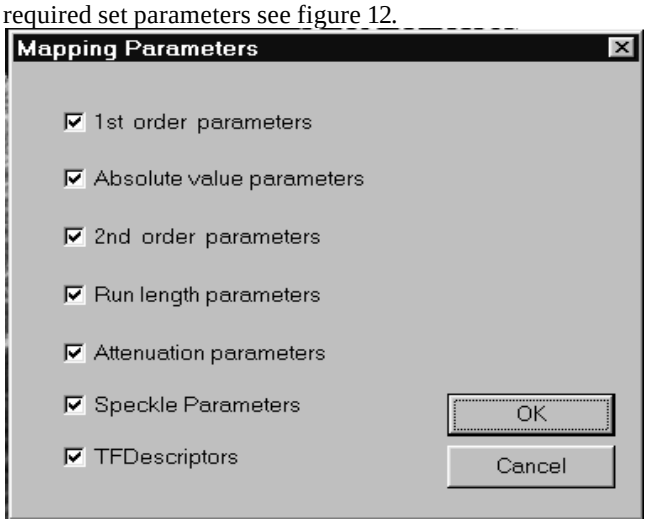

Figure 12: A dialogue for the selected parameters to map it.

When you press OK, the mapping is calculated.

Here are some examples for this mapping of the kidney ROI.

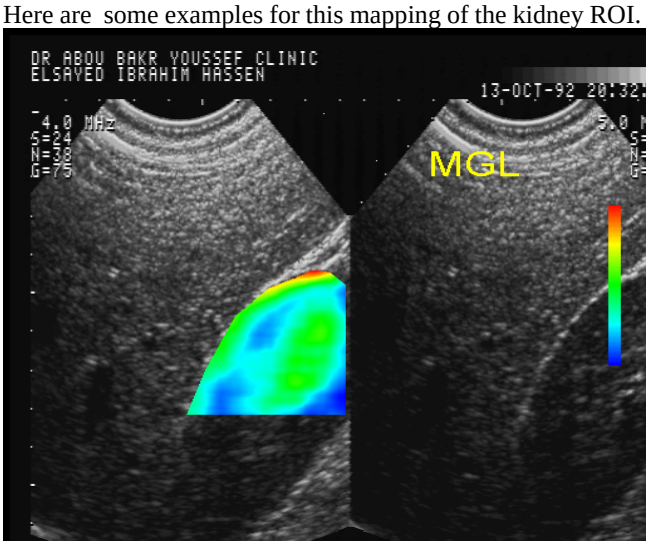

Figure 13: ROI mapping for the mean greylevel (MGL) showing regions of high mean and regions of low mean , the bar code in the right side showing the code for mean.

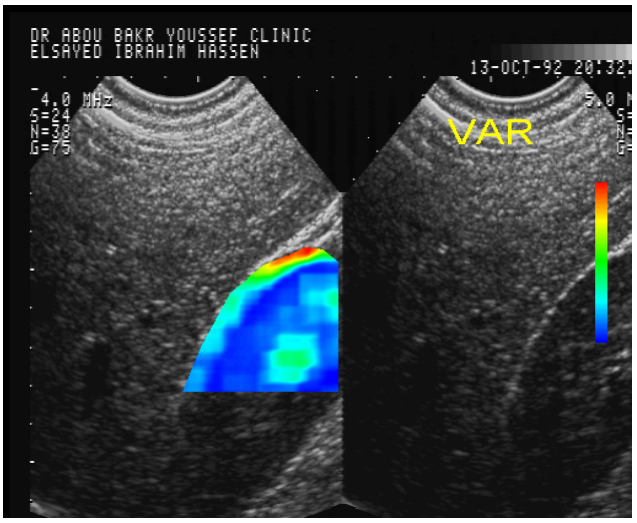

Figure 14: ROI mapping for the variance (VAR) showing regions of high variance at the periphery and inside and regions of low variance values in the middle.

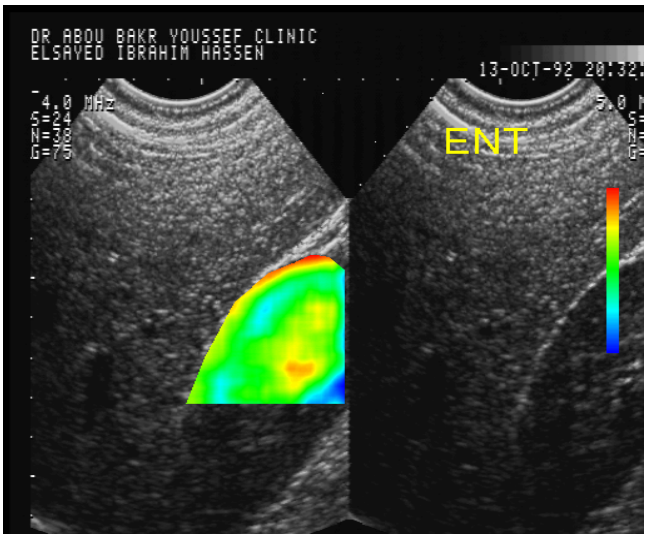

Figure 15: ROI mapping for the Entropy (ENT).

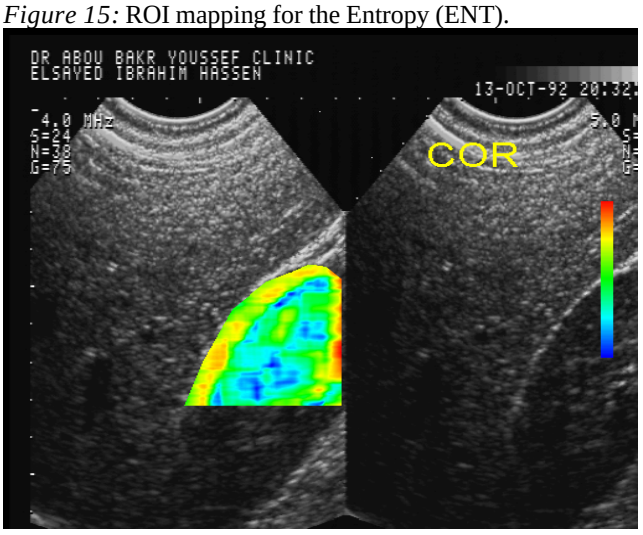

Figure 16: ROI mapping for the Correlation (CORR).

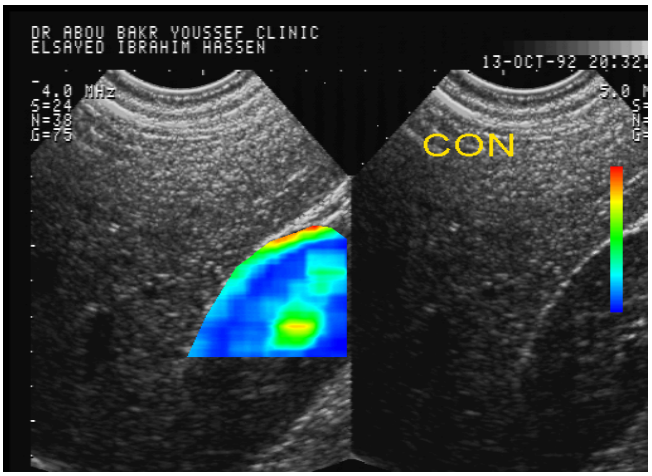

Figure 17: ROI mapping for the Contrast (CON).

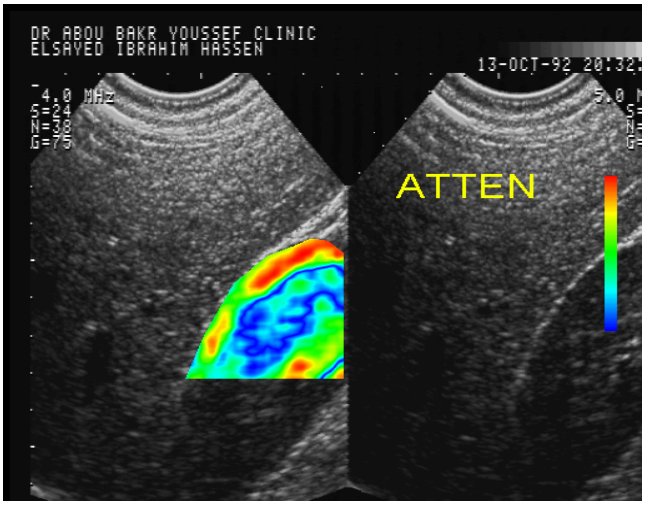

Figure 18: ROI mapping for the Attenuation (ATTEN).

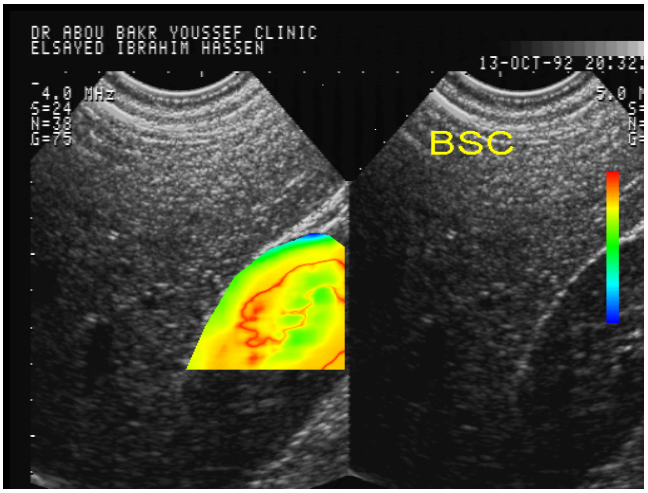

Figure 19: ROI mapping for the Backscatt. Coeffic. (BSC).

Diagnosis

After the selection of ROI and calculation of parameters the user is asked to diagnose the liver using one of the three diagnostic classification techniques as fuzzy rules, fuzzy similarity and neural networks where for every method he will get the contribution to every pathology.

Here is example from the screens of diagnosis for the liver where there is only three liver pathologies, Cirrhosis, Fatty, and Normal livers, see figure 20-23.

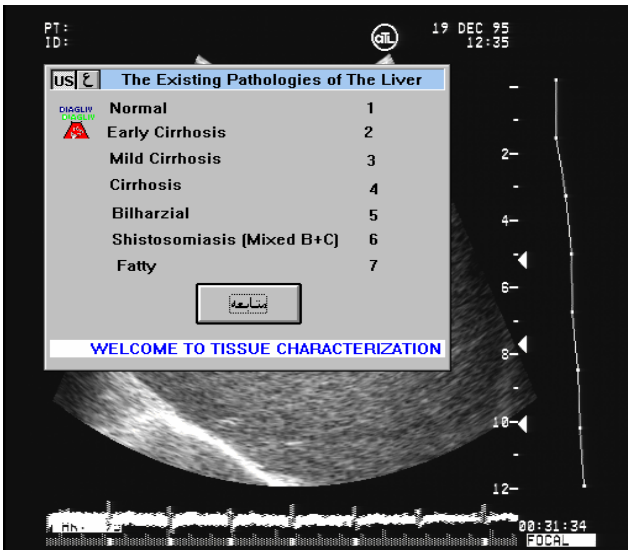

Figure 20: Existing pathologies in our program

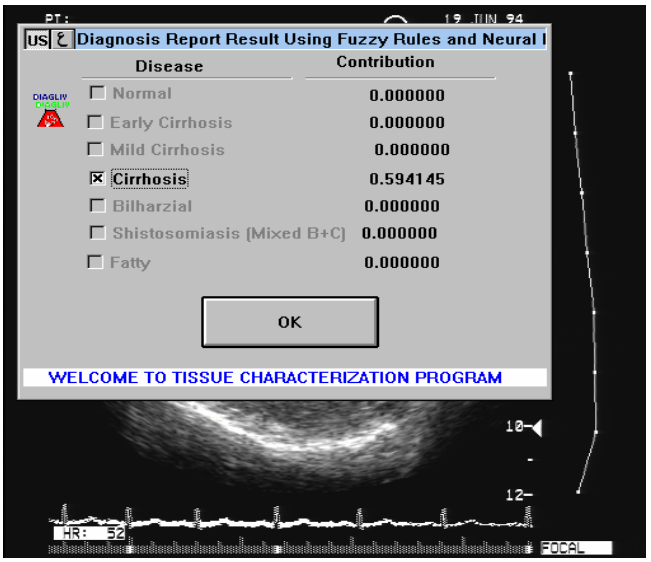

Figure 21: Diagnosis of a Cirrhotic case using fuzzy logic rules.

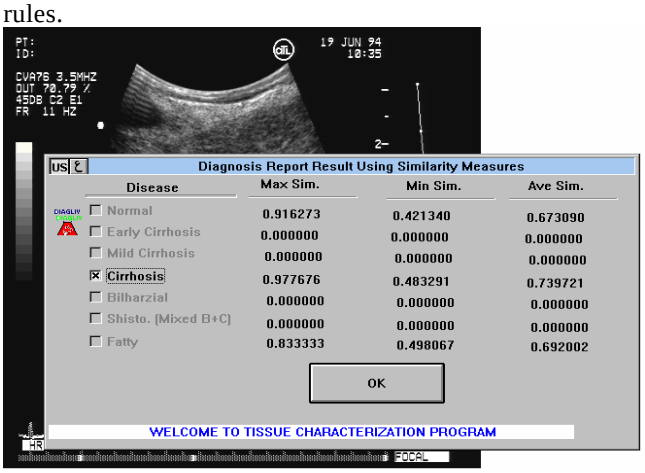

Figure 22: Diagnosis of a Cirrh. case using fuzzy similarity measures.

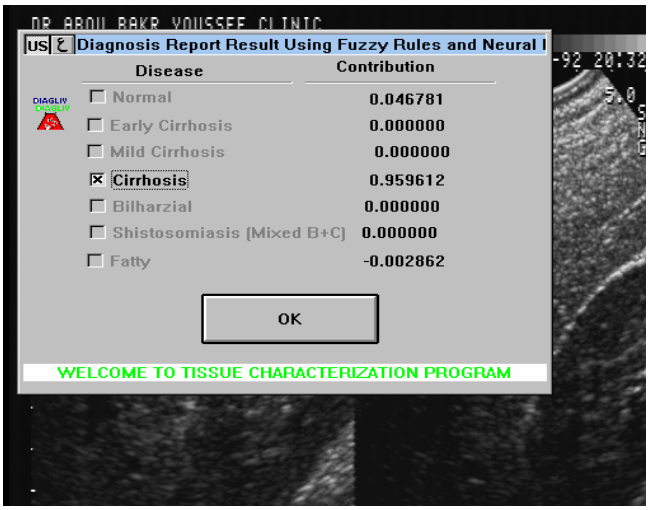

Figure 23: Diagnosis of a Cirrh. case using Neural Network.

5. DISCUSSION AND CONCLUSION

Variations in structural properties in the soft tissue organs like liver are reflected in the ultrasound B-mode image structure and brightness. Using such a QTCS we can know the variations in such a properties with diseases.

Quantitative tissue characterization is a very important tool that can support physician's decision making about the pathology of the organs using ultrasound system linked with a computer acquisition system. The system is cheap, I mean all what you need is just a computer with an acquisition card capable of acquiring images at 8 bits/pixels in minimum of 512*512 pixles and the ultrasound system already available at physician's clinics or at the hospitals.

The QTCS called "DIAGNOSTICS" is very useful for the sonographers. It can help them to judge the case objectively not subjectively as they currently do using the visual inspection for the ultrasound B-mode image. This program can be used with for tissue organ provided that the B-mode ultrasound images have echo texture patterns. The maps or physical profile for the ultrasound properties of the tissues can help a lot in the diagnosis of focal lesions of the breasts, thyroid, liver, spleen, and kidney, and this is difficult using conventional greyscale B-mode scans.

REFERNCES

[1] Gosnik BB, Lemon SK, et al, "Accuracy of ultrasonography in diagnosis of hepatocellular disease", AJR, pp, Vol.,133,19-23, 1979.

[2] Diagnostic accuracy of computerized B-scan texture analysis and conventional ultrasonography in diffuse parenchymal and malignant liver disease", J. of Clin. Ultras., 13:87-99, Feb., 1985.

[3] Chung-Ming Wu, Yung-Chang Chen, and Kai-Shang Hsieh, Texture Features for Classification of Ultrasonic Liver Images., IEEE Trans. on Medical Imaging, Vol. 11, NO. 2, June 1992.

[4] D. Sclaps, U. Rath, J. F. Volk, I. Zuna, A. Lorentz, K. J. Lehmann, D. Lorentz, G. V. Kaick, W. J. Lorentz, Ultrasonic tissue characterization using a diagnostic expert system. In bacharach, S. L. edn. :Information processing in medical imaging, p. 343, Martinus Nijhoff, Dordecht, 1886.

[5] A. M. Badawi, A. M. Youssef, Effect of Static Compression on the Acoustical and Textural Parameters of the Liver with Correlation to Diffuse Diseases, Annual Meeting of Egy. Society of Gastro. and Egy. Soc. of Ultras., December 1992.

[6] A. M. Badawi, A. M. Youssef, Tissue Characterization of Diffuse Liver Diseases Using Neural Nets, Annual Meeting of Egy. Soc. of Gastro. and Egy. Soc. of Ultrasonography, December 1992.

[7] Y. M Kadah, A. A. Farag, J. M. Zurada, A. M. Badawi,A. M. Youssef, Quantitative algorithms for tissue characterization of liver diseases from ultrasound images, IEEE Medical Imaging journal, vol. 3, August, 1996.

[8] Insana M. F, Wagner R. F., Garra B. S. et al,"Analysis of Ultrasound Image Texture via Generalized Rician Statistics", Opt Eng. 225:743, 1986

[9] Nicholas D, "Evaluation of Backscattering Coefficients for Excised Human Tissues, Results, Interpretation and Associated Measurement", Ultrasound Med Biol 8:17,1982

[10] D. Sclaps, U. Rath, J. F. Volk, I. Zuna, A. Lorentz, K. J. Lehmann, D. Lorentz, G. V. Kaick, W. J. Lorentz, "Ultrasonic tissue characterization using a diagnostic expert system". In bacharach, S. L. edn. :Information processing in medical imaging, p. 343, Martinus Nijhoff, Dordecht, 1886.

[11] Ming-Huwi Horng, Yung-Nien Sun, Xi-Zhang Lin and Chien-I Chang,´Texture Feature Coding Method for Classification of Liver Sonography´, IEEE Med. Imaging in preparation.

[12] Kevin J. Parker, Robert M. Lerner, Robert C. Waag,"Comparison of techniques for invivo attenuation measurements",