Image enhancement technique on Ultrasound Images using Aura Transformation

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ABSTRACT

The role of medical scans is vital in diagnosis and treatment. There is every possibility of distortion during the image acquisition process, which may badly affect the diagnosis based on these images. Thus, image processing has become an essential exercise to extract the exact information from the medical images or scans. In recent times, researchers made various attempts to enhance the biomedical images using various signal processing methods. Several techniques have been explored and reported for improving the quality of the medical images. Still, there is a scope of improvement in the area of quality enhancement of the medical scans. In this paper, we investigated an aura based technique for enhancing the quality of medical ultrasound images. An algorithm has been developed using aura transformation whose performance has been evaluated on a series of diseased and normal ultrasound images.

KEYWORDS

ULTRASOUND, IMAGE PROCESSING, MEDICAL MAGING, AURA TRANSFORMATION.

1. INTRODUCTION

Medical imaging is an important source of diagnosing the malfunctions inside human body [1]. Some crucial medical imaging instruments are X-ray, Ultrasound, Computed Tomography (CT), and Magnetic Resonance Imaging (MRI). Medical ultrasound imaging is one of the significant techniques in detecting and visualizing the hidden body parts. There could be distortions due to improper contact or air gap between the transducer probe and the human body. Another kind of distortion that may occur during ultrasound imaging is due to the beam forming process and also during the signal processing stage [2]. In order to overcome through various distortions, image processing has been successfully used [3]. Image processing is a significant technique in medical field, especially in surgical decisions. Converting an image into homogeneous regions has been an area of hot research from a decade, especially when the image is made up of complex textures. Various techniques have been proposed for this task, including spatial frequency techniques [4] [5]. Image processing techniques have been used widely depending on the specific application and image modalities. Computer based detection of abnormal growth of tissues in a human body are

preferred to manual processing methods in the medical investigations because of accuracy and satisfactory results. Several methods for processing the ultrasound images have been developed. The different methods of analyzing the scans can be classified under five broad categories. These are methods based on statistics (clustering methods) [6], fuzzy sets theory [7], mathematical morphology [8], edge detection [9], and region growing [10]. Image processing of ultrasound image allows extracting the invisible parts of human body and provides valuable information for further stages of the quantitative evaluation. Various methods have been proposed for processing ultrasound scans to make effective diagnosis [11-16]. However, there is still a scope for improvement in terms of the quality of processed images.

Recently, an effective technique called aura, introduced by Rosalind W. Picard and Ibrahim Elfadel, has been reported and applied for the analysis of the textures, restoration of the distorted images, and segmentation of the geometrical patterns [17-22]. Even though many techniques have been used for analysis of the ultrasound images, the broad use of aura based techniques has not been reported yet.

In this paper, an aura based technique is investigated for enhancing the quality of the ultrasound images for better medical diagnosis. Extensive investigations have been carried out with ultrasound images involving different problems. The processed images, using aura based algorithm, indicates the enhancement of the important regions of the ultrasound images. The details of medical ultrasound imaging have been presented in the next section. In the subsequent sections, Aura transformation, mathematical background of aura, methodology, and results have been discussed.

2. ULTRASOUND IMAGING

Ultrasound imaging plays crucial role in cardiology, obstetrics, gynecology, abdominal imaging, etc., due to its non-invasive nature and capability of forming real time imaging. Medical Ultrasound imaging is done by using ultrasonic waves between 2 to 20 MHz range without the use of ionizing radiation [23]. The basic principle in ultrasound imaging is that the ultrasonic waves are produced from the transducer and penetrates in the body tissues and when the wave reaches an object or a surface with different texture or acoustic nature, some fraction of the this energy is reflected back. The echoes so produced are received by the apparatus and changed into electric current. These signals are then amplified and processed to get displayed on CRT monitor [24]. The output image so obtained is known as ultrasound scan and the process is called as ultrasonogram. There are different modes of ultrasound imaging. The most common modes are (a) b-mode (the basic two-dimensional intensity mode), (b) m-mode (to assess moving body parts (e.g. cardiac movements) from the echoed sound), and (c) Color mode (pseudo coloring based on the detected cell motion using Doppler analysis) [2].

Ultrasound imaging technique is inexpensive and is very effective for cyst and foreign element recognition inside the human body [25].

3. AURA TRANSFORMATION

Aura transformation is mainly used for analysis and synthesis of textures [26] [27]. It is defined as the relative distribution of pixels intensities with respect to a predefined structuring element. The

matrix computed from the local distribution of pixel intensities of the given texture is called aura matrix. Aura set and aura measure are the basic components of the aura based texture analysis. Aura set describes the relative presence of one gray level in the neighborhood of another gray level in a texture and its quantitative measure called aura measure. Xuejie Qin and Yee Hong Yang also used the aura based framework and showed that basic gray level aura matrices (BGLAM) can uniquely represent the given texture [28]. A neighborhood element is used to calculate the relative presence of one gray level with respect to another. The concept of Aura has also been applied to 3D textures to generate the solid textures from the input samples automatically without user intervention. The results computed using weighted-aura matrix distance, outperform Wei and Levoy's method and are comparable to that proposed by Jagnow, et. al [29].

Various techniques have been investigated for image processing in literature [30-35] [18-20]. Our present work is based on recently proposed BGLAM (Basic Gray-Level Aura Matrices) mathematical framework [28], which is developed based on the aura concepts (i.e., aura sets, aura measures, and aura matrices) [33]. The aura transformation for texture analysis and synthesis may have many advantages. The main advantage is that the input texture image is not needed once the aura matrix has been calculated. This reduces the storage and computational complexity. Another advantage is that aura matrix is independent of its orientation. Hence each texture can be uniquely represented. In addition, this technique may further be used for constructing aura based distance measures for comparing the textures. The aura can also be explored for implementing different types of digital filters and also to estimate the boundary of different components in images of solids and fluids [24]. The output texture can be generated by the concatenation of the input texture sample that introduces a very serious problem of propagating the distortions present in the input sample to the synthesized texture. The sources of distortion may be due to the presence of random noise, wrinkles, foldings, cracks, rusting, etc. Further, the problem is inflated if these distortions are present near the edges. The net result of these distortions may be unpleasing and distracting effects developed in the synthesized output textures [24].

4. MATHEMATICAL BACKGROUND OF AURA

As discussed earlier, aura is a significant technique for analysis and synthesis of textures. The mathematical framework of aura is defined in [26-28] [18-21]. The input texture is represented as an ordered set of pixel intensity values. It is denoted by S and has the size $N \times M$.

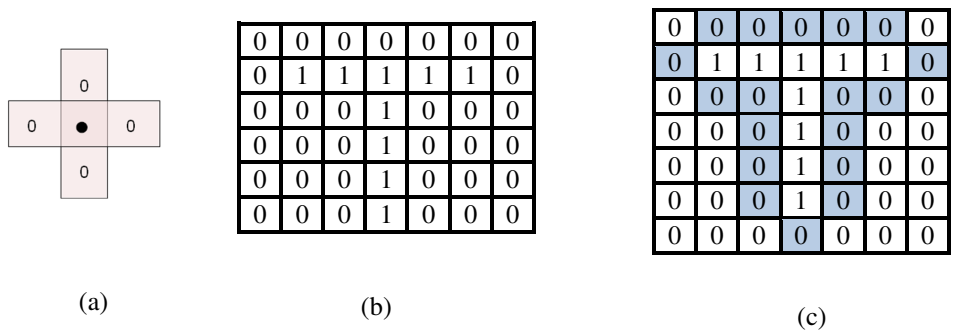


Fig. 1. Example of an aura on a binary lattice with four nearest neighbors system. (a) A sample binary lattice S, where the subset A is the set of all 1's and B the set of all 0's. (b)The structuring element of the neighborhood system (c) The set of shaded sites is the aura set of A with respect to B.

The structuring element is a collection of pixel intensities taken from site where it is placed on the input texture image. After placing this element at a particular site, the intensity values taken from two sets called Set A and Set B are matched with the pattern of the pixel values of the image just below the structuring element. The choice of shape of the structuring element depends on the nature of analysis and the input image. The values of intensities used for A and B depends on the input image and the nature of the analysis. Various schemes for assigning the intensity values to sets A and B lead to different aura patterns. In general, the structuring element is denoted by $N = \{N_s, s \in S\}$, where, N_s is one of the elements (single pixel intensity) taken from the set S or its subset A or subset B. The elements around which the aura is to be determined are taken from the set A. The intensity values of the surrounding elements are taken from the set B. The set of matching patterns in the given texture image as per the structuring element is called aura matrix.

Mathematically, the aura of A w.r.t. B is given by,

$$\vartheta_B(A) = \bigcup_{s \in A} (N_S \cap B) \qquad (1)$$

The total number of aura patterns obtained for a combination of pixel intensity values taken from set A and set B according to the structuring element is called the aura measure for that combination and is given by

$$m(P_A, P_B) = \sum_{P_t = P_{AB}} |P_t \cap P_{AB}| \qquad (2)$$

where |Pt ∩ PAB| represents the total number of elements in the given set. P_A and P_B are the patterns formed by taking elements from set A and set B, respectively according to the structuring element. P_t is the pattern formed in the input texture at the position where the structuring element is currently placed. P_{AB} is the pattern formed from the elements set A and set B. Hence the aura measure for a combination of P_A and P_B at a particular site in the input texture is equal to total number of matchings of all possible patterns formed from set A & set B with respect to the pattern formed below the current position of the structuring element. It should be noted that the matching of patterns is to be computed only at the sites where the intensity values in the input texture are identical to the elements in set A

The matrix of all the patterns which can be formed for different combinations of the intensity values taken from set A and B with respect to the given structuring element is called aura matrix. For simplicity the image textures are analyzed using their gray level representations. GLAM (Gray-Level Aura Matrix) defines the aura measure for a typical the structuring element and the texture image shown in Fig. 1 between S_i and S_j using the relation

$$\lfloor a_{i,j} \rfloor = m\lfloor S_i, S_j \rfloor \qquad (3)$$

where S_i and S_j are the ith and jth gray levels in the range

$$\{0 \le i, j \le 1\}.$$

5. METHODOLOGY

From the literature survey, it is observed that limited work has been done using the concepts of aura based transformation. Our previous investigations have shown that the power of aura transformation may be enhanced by modifying some of the concepts of aura technique [18-22]. In the present work, the basic concept of aura is further modified to widen its application area. Here, modified aura concept has been used for investigating and enhancing the quality of ultrasound images for better medical diagnosis. The modified aura based algorithm is shown in Fig. 2 in the form of a flow chart.

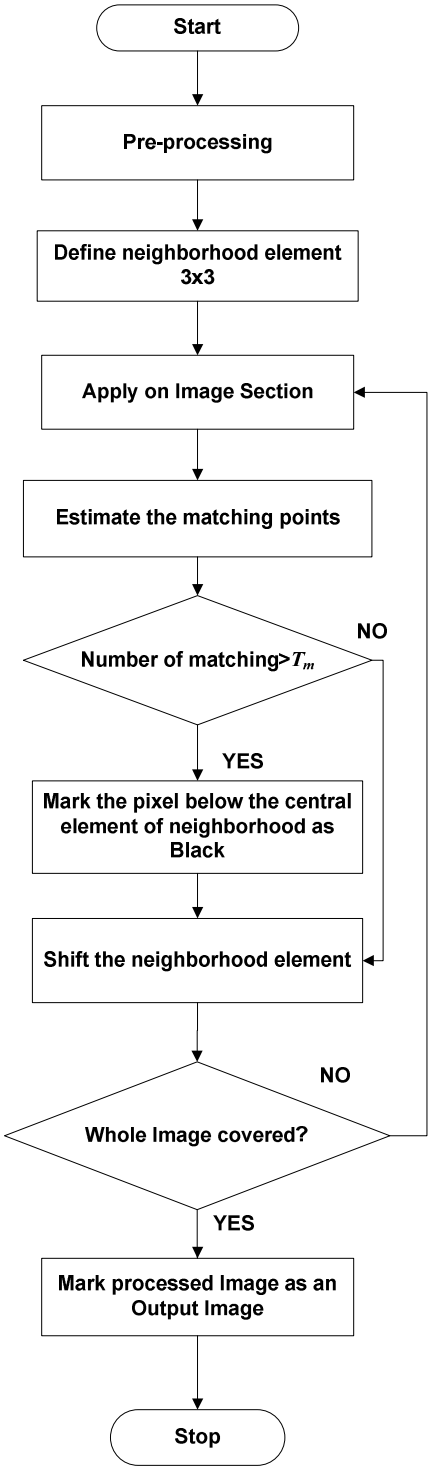


Fig. 2. Flow chart for Aura based processing of MRI

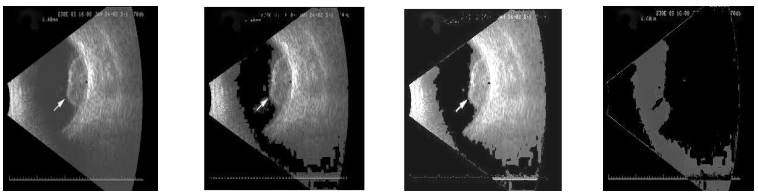
In preprocessing step, the input ultrasound images are converted to gray scale and its size are modified to reduce the number of computations. The reduction depends on the expected size and texture of the abnormal region in the scan.

Different types of normal and diseased ultrasound images are processed for investigating the effect of aura on the neighborhood structures of the images. A neighborhood element is defined in the form of a 3×3 matrix.

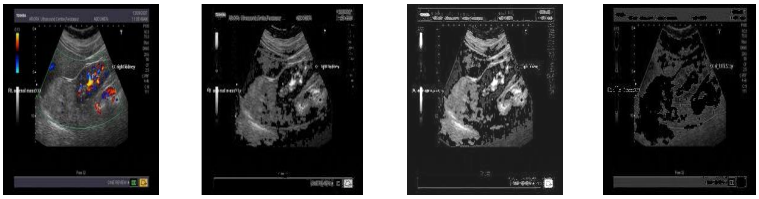
The values of the elements of this matrix are estimated on the basis of gray scale values of the given ultrasound image. The input image is processed using this structuring element by traversing it pixel by pixel on the whole image. At every placement, the differences of the gray scale values of the neighborhood elements and the corresponding pixels below it are computed. Depending upon the difference threshold Td, the 3×3 matrix of the differences is converted to zeros and ones. If the difference is less than Td, the corresponding element is mar ked as one otherwise, zero in the difference matrix. If the total number of ones in the difference matrix is more than a threshold value called matching threshold Tm, the pixel corresponding to the central element of the neighborhood element is marked as black, otherwise left unchanged. This process is repeated for the entire input image. The investigations have been carried out with different values of both the thresholds and input ultrasound images. The evaluation for the enhancement in the processed ultrasound image with respect to the input image was carried out using the visual inspection.

6. RESULTS

The investigations were carried out using two sets of ultrasound images. The first set incorporated the diseased images and the second set included the normal images corresponding to different subjects. The images in these two sets were processed as per the modified aura methodology described in the previous section. The results were obtained by modifying the values of the thresholds Td and Tm. Some of the processed images are shown in Fig. 3.



1(a) 1(b) 1(c) 1(d)



2(a) 2(b) 2(c) 2(d)

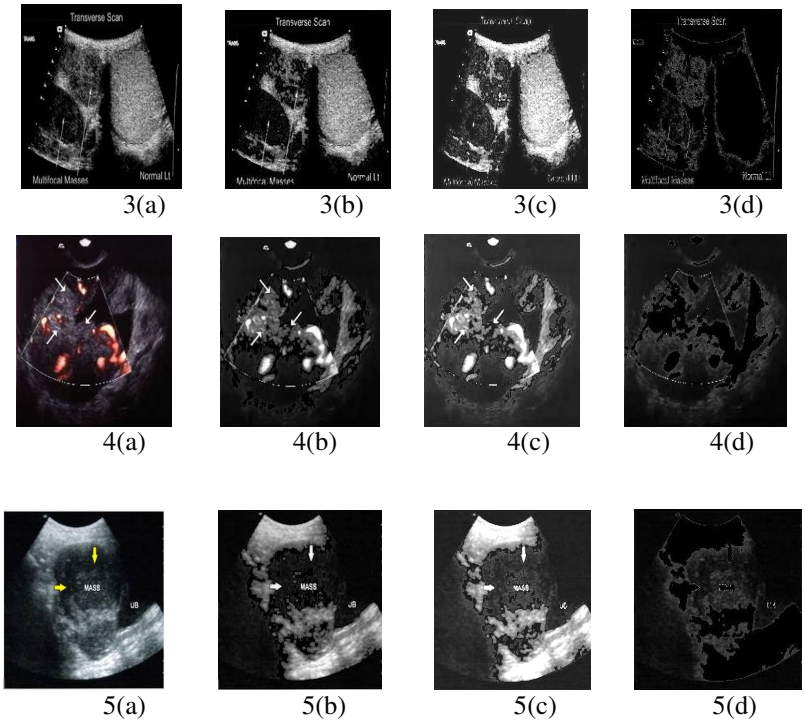


Fig. 3. Input and the corresponding processed medical ultrasound images with different threshold values.

The input images are shown in the column I. The value of Td for these images was fixed at 30% of the maximum intensity value in the image under consideration. The corresponding processed images for values of Tm as 3, 5, and 9 are shown in columns II-IV, respectively.

The visual analysis of the processed images with respect to the input images shows that the enhancement is better for the moderate values of the matching threshold i.e. around Tm = 5. As the value of Tm increases beyond 5, the quality of the processed images started deteriorating. Similarly, it was also observed that when the value of difference threshold Td was fixed in the range 25 -30 percent of the maximum intensity, better enhancement was achieved.

7. CONCLUSION

In this study, investigations were carried out to enhance the quality of the ultrasound images using modified aura based transformation. It was observed that this transformation technique is relatively less expensive, simple, and promising.

The duration for processing the image is very less. The investigations further showed that the processed ultrasound images were enhanced in quality. The enhanced images may be used for predicting the diseases inside the human body more effectively and accurately. The investigations involving the images obtained from other medical imaging techniques are in our future plan.

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