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# Enhancement of ultrasound images using fuzzy sets and comparing the results of Radon and Fourier transforms

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**Abstract**
This paper presents an adaptive image enhancement method through fuzzy set based on speckle detection and contrast enhancement for ultrasound images. The main idea is to enhance the tissue structure and also smooth the speckle regions adaptively from pre-defined fuzzification techniques and radon transform. We firstly fuzzy the original image by S function which can be determined by the maximum entropy principle. Subsequently, we apply the radon transform and add in a filter of triangular function for removing unnecessary signal. Big similarity values means speckle pixels needed smoothing from low pass filtering, and small values correspond to structure pixels. Test images show that our new method can enhance tissue structure and also reduce speckle for better image quality.

**Keywords**
Ultrasound; Enhancement; Fuzzy set; Radon transform

## I. Introduction
Image enhancement improves the quality (clarity) of images for human viewing. Removing blurring and noise, increasing contrast, and revealing details are examples of enhancement operations. For example, an image might be taken of an endothelial cell, which might be of low contrast and somewhat blurred. Reducing the noise and blurring and increasing the contrast range could enhance the image.

### A. Why we need ultrasound image enhancement?
Ultrasound is becoming a major tool in medical diagnostics due to its non-invasive and non radiation properties. The problem with this technology is low resolution and high noise, making the pictures difficult to read and diagnose. Accoustic View has a goal to make ultrasound the leading diagnostic tool by enhancing its resolution and reducing the noise associated with the images.
Clinicians are becoming increasingly reliant on ultrasound techniques due to some advantages, such as convenient, noninvasive and real-time scanning. Recently, technical advances in diagnostic ultrasound can help clinicians diagnose unknown disease with the visualized information in patients' anatomy. Specifically, the technique has been valuable potential for the examinations in maternal fetal bonding or gynecology problems.

### B. Disadvantages of speckle
Ultrasound speckle could lead clinicians to interpret difficultly. Similarly, operation settings of the limited contrast of ultrasound image may cause some problems in the differentiation of soft tissues or lesions from their surroundings.

### C. Advantages of the image enhancement
To improve the image quality and supplement deficiencies of the contrast. A lot of previous works have presented various enhancement methods, such as histogram equalization, filtering enhancement, and noise reduction technique .However, the most important drawback is that the enhancement algorithm does not consider human visual perception and therefore it is impractical for clinical diagnosis. Furthermore, the effects of under enhancement and over enhancement are another problem to be overcome.

## II. Image Enhancement Techniques
Histogram equalization is a method in image processing of contrast adjustment using the image's histogram. This method usually increases the global contrast of many images, especially when the usable data of the image is represented by close contrast values. Through this adjustment, the intensities can be better distributed on the histogram. This allows for areas of lower local contrast to gain a higher contrast. Histogram equalization accomplishes this by effectively spreading out the most frequent intensity values.
The method is useful in images with backgrounds and foregrounds that are both bright or both dark. In particular, the method can lead to better views of bone structure in x-ray images, and to better detail in photographs that are over or under-exposed. Histogram equalization often produces unrealistic effects in photographs.

### A. Spatial filtering
In spatial filtering, a lens is used to focus the beam. Because of diffraction, a beam that is not a perfect plane wave will not focus to a single spot, but rather will produce a pattern of light and dark regions in the focal plane. For example, an imperfect beam might form a bright spot surrounded by a series of concentric rings, as shown in the Fig. to the right. It can be shown that this two-dimensional pattern is the two-dimensional Fourier transform of the initial beam's transverse intensity distribution. In this context, the focal plane is often called the transform plane. Light in the very center of the transform pattern corresponds to a perfect, wide plane wave. Other light corresponds to "structure" in the beam, with light further from the central spot corresponding to structure with higher spatial frequency.

### B. Noise reduction
Noise reduction is the process of removing noise from a signal. Noise reduction techniques are conceptually very similar regardless of the signal being processed, however a priori knowledge of the characteristics of an expected signal can mean the implementations of these techniques vary greatly depending on the type of signal. All recording devices, both analogue or digital, have traits which make them susceptible to noise. Noise can be random or white noise with no coherence, or coherent noise introduced by the device's mechanism or processing algorithms.
The most important drawback is that the enhancement algorithm does not consider human visual perception and therefore it is impractical for clinical diagnosis. Furthermore, the effects of under enhancement and over enhancement are another problem to be overcome.

## III. Research Methodology

### A. Fuzzy Set Processing
To enhance image contrast which can be more approaching to the human visual perception.for the same we proceed with the three successive steps : (a) fuzzification, (b) suitable membership values modification, and (c) defuzzification.

### 1. Normalization

As the brightness and the contrast level varies dramatically in ultrasound image. So we need to normalize the gray scale level of the image so that it can be generalized in such a way that we can easily apply the image enhancement process. Now in normalization we will map the different gray levels into the identical range [0,1] by the membership function

```
member_image(i,j)=255*((double(img(i,j)-img_min))/double(diff));
```

where img_min and img_max are the minimum and maximum gray levels of the original image respectively, and img(i, j) are the gray levels of pixel (i, j).

### 2. Fuzzification

Based on the knowledge of fuzzy theory, the ultrasound images can map all the pixels of a set into the real numbers in [0,1] by choosing appropriate fuzzy set for further estimation. In this approach, we applied the fuzzy set of S function not only to map the image to the fuzzy domain, but to utilize the membership values of its gray levels for further process. The S function is listed as follows:

$$S(\mu_A ;a,b,c)= \begin{cases} 0 & \text{if } \mu_A \le a, \\ (\mu_A(g)-a)^2/(b-a)(c-a) & \text{if } a<\mu_A \le b, \\ 1-(\mu_A(g)-c)^2/(c-a)(c-b) & \text{if } b<\mu_A \le c, \\ 1 & \text{if } \mu_A > a, \end{cases}$$

where a, b and c are the parameters that determine the shape of S function. In this calculation, we applied the maximum entropy to determine specific numbers of the parameters and the formula can be defined by

Entropy = max(pd1(t))+max(pd2(t));

where pd1(t) and pd2(t) are probability distributions of gray level below and above than the threshold gray level : respectively, and the optimal threshold, !max, can be obtained by maximizing the sum of the pd1(:) and pd2(:). After the fuzzification process, the ultrasound image is transformed from the gray level into the fuzzification domain by

mu_image(I,j) = S(μA ; a,tmax,c)

The parameters of a and c are the gray levels from the search of the first peak and last peak of image histogram respectively.

### Results

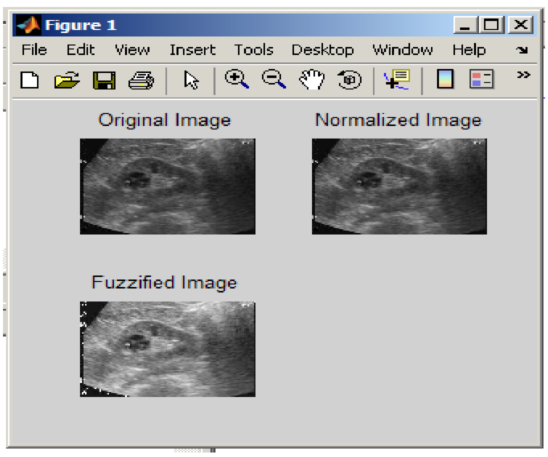


Fig. 1

In this study, we have presented the results and compared them using the proposed approach. The computation procedure of performing the image enhancement algorithm is shown and elucidated in the Fig. 1. The S function was selected as image fuzzification and the parameters of the cut points were automatically determined by using the maximum entropy principle. Based on the fuzzified images, we added a radon transform for further process. The advantage of using radon transform is that the process can adapt to the local image texture by automatically altering the fuzzification image so that the enhancement process is appropriately optimized. By employing the enhancement algorithm, not only the brightness of lesions became more obvious, but also the edge for the lesions exhibited distinctly.

In the comparison with the original image and the enhanced image, the proposed method provides very effective and practical performance in contrast enhancement. The experiment results are shown with two advantages:

(1) The lesion textures of ultrasound images are with better enhancement by the proposed method but the detail structures are preserved;

(2) The degree of the enhancement is suitable for the human vision perception.

Traditional methods for the image enhancement focus on the properties of contrast ratio of the processed image but ignoring the importance of the human visual perception. From the automatic processes of the optimum enhancement, the computerized enhancement process such as proposed algorithm is used to display an image that improves the matching characteristics of the human visual system.

### 3. Defuzzification

Defuzzification is the process of producing a quantifiable result in fuzzy logic, given fuzzy sets and corresponding membership degrees. It is typically needed in fuzzy control systems. These will have a number of rules that transform a number of variables into a fuzzy result, that is, the result is described in terms of membership in fuzzy sets. For example, rules designed to decide how much pressure to apply might result in "Decrease Pressure (15%), Maintain Pressure (34%), Increase Pressure (72%)". Defuzzification is interpreting the membership degrees of the fuzzy sets into a specific decision or real value.

```
ind1= abs(x)<=Threshold;
ind2= abs(x)>Threshold;
pd1=prob_dist(ind1);
pd2=prob_dist(ind2);

Entropy=max(pd1(:))+ max(pd2(:));
```

After the deffuzzification process, the reconstructed image is shown the enhancement efficacy by replacement of the original image.

## IV. Radon Transform

The Radon transform is widely applicable to tomography, the creation of an image from the scattering data associated to cross-sectional scans of an object. If a function *f* represents an unknown density, then the Radon transform represents the scattering data obtained as the output of a tomographic scan. Hence the inverse of the Radon transform can be used to reconstruct the original density from the scattering data, and thus it forms the mathematical underpinning for tomographic reconstruction, also known as image reconstruction. The Radon transform data is often called a sinogram because the Radon transform of a Dirac delta function is a distribution supported on the graph of a sine wave. Consequently the Radon transform of a number of small objects appears graphically as a number of blurred sine waves with different amplitudes and phases. The Radon transform is useful in computed axial tomography (CAT scan), bar code scanners, electron micro scopy of macromolecular assemblies like viruses and protein complexes, reflection seismology and in the solution of hyperbolic partial differential equations.

The Radon transform, R$f$, is a function defined on the space of straight lines L in R2 by the line integral along each such line:

$$Rf(L) = \int_L f(\mathbf{x})\,|d\mathbf{x}|.$$

Concretely, any straight line L can be parametrized by

$$(x(t), y(t)) = \big((t\sin\alpha + s\cos\alpha), (-t\cos\alpha + s\sin\alpha)\big)$$

where s is the distance of L from the origin and α is the angle the normal vector to L makes with the x axis. It follows that the quantities (α,s) can be considered as coordinates on the space of all lines in R2, and the Radon transform can be expressed in these coordinates by

$$\begin{aligned} Rf(\alpha, s) &= \int_{-\infty}^{\infty} f(x(t), y(t))\,dt \\ &= \int_{-\infty}^{\infty} f\big((t\sin\alpha + s\cos\alpha), (-t\cos\alpha + s\sin\alpha)\big)\,dt \end{aligned}$$

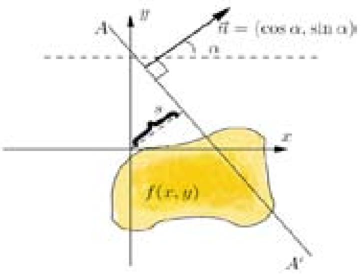


Fig. 2 :

## V. Comparison Of Experimental Results With Those Of Fourier Transformation

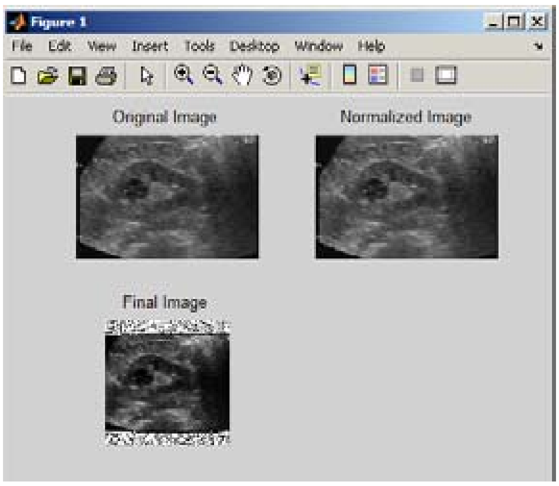


Fig. 3 : Radon Results


Fig. 4 : Fourier Results

## VI. Conclusion

In this study, the proposed technique based on the combination of fuzzy logic and radon transform has been successfully implemented, and our results were shown the potentiality to be a useful procedure for image enhancement in ultrasound images. Also it can provide the clinicians to interpret the hidden or vague information existed in the ultrasound images. Traditional enhancement is providing a poor quality of obscure image, and it is not suitable for the clinical diagnosis. In the simulation results of ultrasound images, we can easily identify the enhanced tissues and lesions instead of unwanted artifact. In conclusion, the performance of the proposed approach confirms that the enhanced method is effective and practical for the clinical diagnosis. Additionally, we expect that it may provide additional benefits to improve the diagnostic accuracy.

Therefore, we can conclude our method exhibit widely applicable for other medical image modalities and general image processing problems. The proposed approach will be examined in the future for including more ultrasound images and involved the radiologists in the clinical evaluation.

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