Application of image restoration algorithms in vibro-acoustography images

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Abstract

Vibro-acoustography (VA) is an imaging modality that produces an image of the mechanical response of an object to a localized dynamic radiation force of an ultrasound field. This technique has been studied and used in clinical applications as to image calcification in breast tissue and arteries. This paper presents the application of restoration algorithms to VA images.

1. Introduction

Elastography is a new field in imaging sciences that images certain elastic properties of objects. Elastography might become a very helpful tool in medical imaging scenario, once elasticity of biological tissues can be related to certain pathologies [2]. VA is an elastography method in which an oscillatory radiation force is used to vibrate a small portion of an object (or a tissue) in the vicinity of the focal region of the system. The produced acoustic emission from the object vibration is detected by a hydrophone and used to form an image of the object [1]. Figure 1 shows a diagram of the VA imaging system.

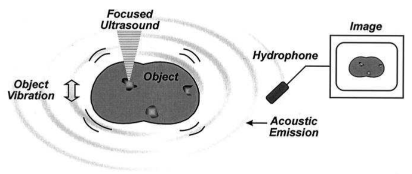


Figure 1. Ultrasound-stimulated vibro-acoustography

This work applies restoration algorithms to VA simulated images. Since we are not aware of works in the literature studying the restoration of VA images, our initial aim is to analyze the behavior of these images to a restoration problem. Thus, we use as input the VA image with noise and try to restore it to its original state using three filters (Wiener, Regularized Least Squares (RLS) and Geometric Mean (GM)). We obtain acceptable results after restoration using these filters.

2. Methodology

In Ref. [3] the VA image formation is studied taking into account depth-of-field effects. The obtained 3D complex PSF of that work is used in this paper to form the image. The magnitude of the PSF is presented in Figure 2.

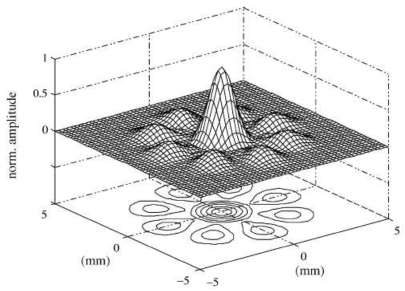


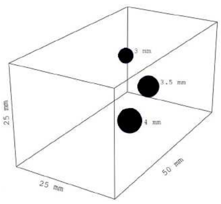
Figure 2. Theoretical PSF magnitude for a sector array transducer

VA imaging systems might be assumed linear and space invariant in an area nearby the focal region of the system [3]. Thus, the VA image of an object can be obtained convolving the function that represents the object with the system PSF: $g(x, y, z) = f(x, y, z) * h(x, y, z) + n(x, y, z)$, where $g(z, y, z)$ is the degraded image, $f(x, y, z)$ is the function of the object, $h(x, y, z)$ is the system PSF and $n(x, y, z)$ is the noise (Gaussian). Therefore, we have the necessary apparatus to obtain a degraded image by blurring and noise, in order to apply restoration techniques.

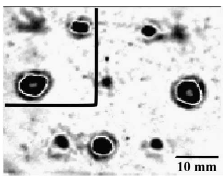
The complex nature of the VA PSF and of the convolution is noteworthy, since the problem involves an amplitude and a phase in each position. Then, we have the first problem: the use of complex convolution. This fact considerably increases the computational costs of both implementing and using restoration algorithms. Another problem is related to the size of the PSF; its discrete representation (3D matrix) has dimensions $512 \times 80 \times 80$. Taking into account that the PSF is a complex function and considering its dimensions, more than 4 GB of memory are needed to execute the process of restoration. The algorithms were applied in the frequency domain and the method known as overlap-add was employed to tackle this problem. We are studying other ways to reduce the complexity as, for instance, the fact that the PSF that has been used is separable in the plane x-y and in the dimension z. Other restoration algorithms will be also applied.

3. Experimental Results

In order to make our experimental tests, we used a digital phantom (see Figure 3(a)), which was designed to mimic the major features exhibited by a breast phantom. The VA image of the breast phantom is shown in Figure 3(b), along with the region described by the digital phantom.



(a)



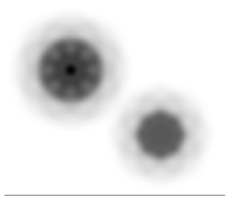
(b)

Figure 3. Digital phantom in 3D (a) VA image of the breast phantom (b)

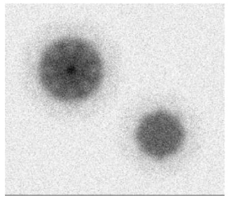
The blurred and degraded (Gaussian noise was added) images are presented in Figures 4(a) and 4(b). Three restoration filters were used: Wiener, Regularized Least Squares (RLS) and Geometric Mean (GM). The restoration visual results are presented in Figure 5 and the quantitative results are summarized in Table 1.

4. Conclusions

This technique was successfully applied to our experimental tests as shown in the results. There are various restoration methods in the literature and this paper, indeed, is the first step in this direction.

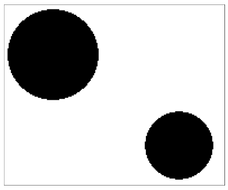


(a)

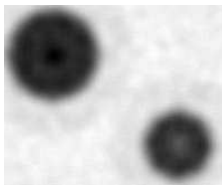


(b)

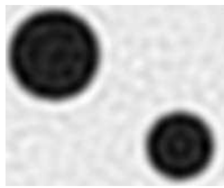
Figure 4. Blurred image (a) Degraded image (b)



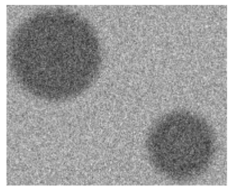
(a) Original phantom



(b) Wiener Filter ($K = 5$)



(c) RLS Filter ($\gamma = 5$)



(d) GM Filter ($\gamma = 1$, $K = 5$ and $\alpha = 1/2$)

Figure 5. Experimental results

Algorithm	Improvement in Signal to Noise Ratio
Geometric Mean	31.17
Wiener	39.76
RLS	43.30

Table 1. ISNR of the results

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