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A Study and Analysis of Speckle Reduction Method in Digital Holography

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***Abstract*— Image denoising has become a very essential in the case of noisy images for better information extraction. On the other hand, processed image must reserve the relevant details of the primary image. This noise suppression is very useful in many applications. Speckle noise is one of the major noises causing digital hologram. So we need some mechanism for denoising the noisy content by preserving the valuable information. This paper presents a comparative study on BEMD (bi-dimensional empirical mode decomposition) and MBEMD (multilevel bi-dimensional empirical mode decomposition) along with the frost filter.**

Keywords- Image denoising, Speckle reduction, Bi-dimensional empirical mode decomposition, Frost filter

I. INTRODUCTION

Digital holograms are images that are projected in the air with the help of light and air as medium. In digital holography, using digitized interferogram, image rendering or reconstruction [1] of object data is performed numerically. Digital holography offers a means of measuring optical phase data and typically delivers three-dimensional surface or optical thickness images. Digital holography has a wide range of applications [2]. Several processing schemes have been developed to assess optical wave characteristics such as amplitude, phase, and polarization state, which make digital holography a very powerful method for metrology applications.

There are several reasons to derive noise in the processing of digital hologram. Generally, the noise comes from three main sources. First, it is related to the optical components, which make multiple interference fringes on the recording plane. Secondly, it comes from the process of set up of the experiment. Because the hologram setup requires a low concentration of the particles which create a spotted diffraction pattern in the CCD (charge couple device) [3] camera. With many particles, several diffraction patterns are superimposed and make speckle noise that disturbs the reconstruction of the particle object. Therefore, speckle noise and white noise will appear when the phase or intensity of the object beam and reference beam is different. Thirdly, digital holograms are captured using a physical system as opposed to an idealized system in computer-generated holography, so there is a lot of wrong information included in the hologram.

The study of the topic was taken, looking at the speckle noise affecting the reconstructed images. This can destroy the image quality. In general we rely on controlling the quality of processed images. In certain cases, the noise can change information which is valuable. These noises must be reduced using some mechanisms. This study compares two speckle reduction methods and suggests the best one. The comparison is done by taking the PSNR values. So this work will be helpful to beginners and researchers in this area.

The reminder of the paper is organized as follows: section II presents about speckle reduction methods. Section II A deals with the concept of BEMD, section II B describes the concept of MBEMD, section III shows the result and discussion. Section IV gives the concluding remarks and finally the paper ends with few references.

II. SPECKLE REDUCTION METHODS

Sound waves are reflected back to the ultrasound machine in different ways, as they are passed. Unfortunately, the quality, i.e., resolution and contrast, of ultrasound imaging is generally limited by noise, also called speckle noise. Speckle noise is a superposition of unwanted spots over objects of interest. It is with the object surface characteristics, due to the behaviour of a coherence source of radiation. Speckle noise affects all coherent imaging systems including hologram images. A number of elementary scatters reflect the incident wave towards the sensor within each resolution cell. A constructive or a destructive interference is undergone in a random manner in different phases of backscattered coherent waves. The random granular pattern, called speckle corrupts the acquired image and delays the interpretation of the image content. This must be reduced. There are several speckle reduction methods [4]. Two important methods are discussed in the remaining section.

A. Bi-Dimensional Empirical Mode Decomposition

The Bi-dimensional Empirical Mode Decomposition (BEMD) [1-3] is a 2D extension of the classical Empirical Mode Decomposition (EMD) [5]. The decomposition is done without making any assumptions on the initial data. EMD is a fully data-driven method. It is used to remove the noise produced in transform process. EMD has a wide range of applications, including geophysics, radar and medicine. In EMD method, the complex datas are decomposed into a small and finite number of components by sifting process, i.e., collection of Intrinsic Mode Functions (IMF). Generally simple oscillatory mode is represented by IMF with the same number of zero crossings and extrema, with its envelopes being symmetric with respect to zero. This decomposition method which operates in the spatial domain is adaptive and highly efficient. This was extended to the field of image processing [6] referred as BEMD Considering the good effect of EMD in processing one dimensional signal.

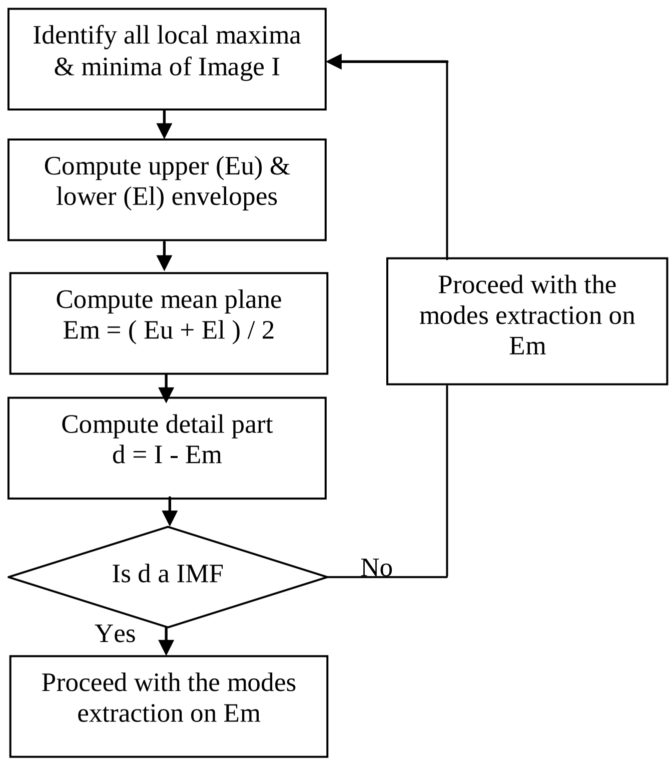

Figure 1. The classical BEMD procedure for IMF extraction

In BEMD, algorithm returns maxima and minima elements of matrix. It is done after reading the data array in the first sifting step considering the peaks through columns of matrix. Based on scattered data, a surface on a 2D grid is estimated. Linear interpolation is done inside triangles by splitting each cell in the grid into a triangle. Then the mean plane is obtained by averaging upper and lower envelope. The classical BEMD procedure for IMF extraction is given in Figure 1.

The original image can be recovered by

$$I = \sum_j IMF_j + R$$

The first IMF contains highest special frequencies, which is to be reduced and R represents residue, i.e., low frequency information. The denoised image is,

$$Imod = \mathrm{I} - \mathrm{IMF1}$$

B. Multilevel Bi-Dimensional Empirical Mode Decomposition

Frequent mode mixing is major disadvantage of BEMD process. i.e., frequent appearance of widely desperate scales in a single IMF. This is overcome using MBEMD method. The sifting process of MBEMD [7, 8] is shown in Figure 2.

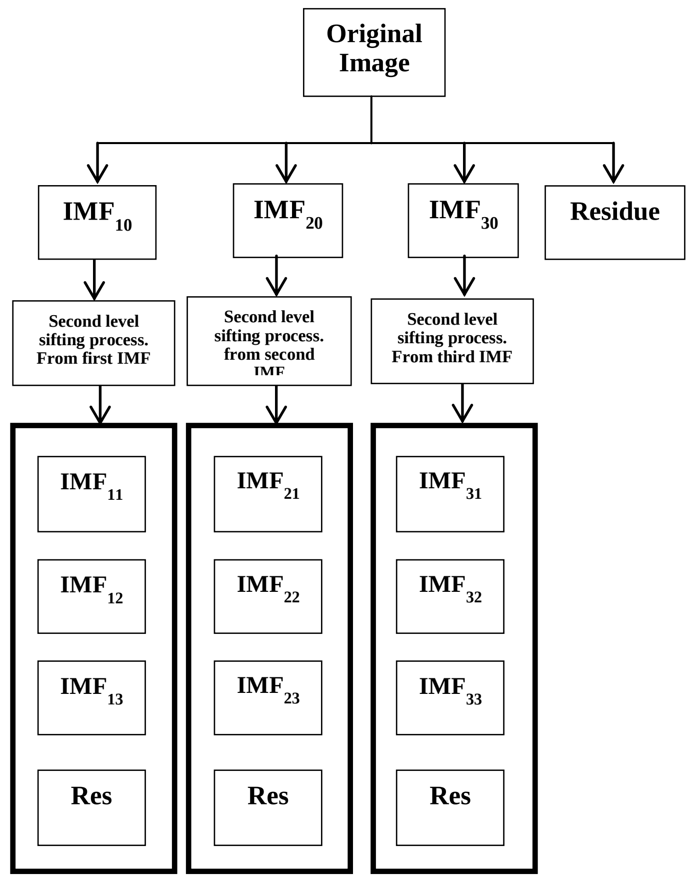

Figure 2. Sifting process of MBEMD

Here, in this approach, the input image is represented by a linear combination of several extracted IMF's (plus residuals). i.e., the sifting process is again processed on each IMF in the BEMD method.

The decomposition levels are as,

$$\mathrm{I}_{\text{first level}} = \sum_{i=1}^{3} \mathrm{IMF}_{i0} + \mathrm{R}$$

$$I_{second\ level} = \sum_{i=1}^{3}\sum_{j=1}^{3} IMF_{ij} + R$$

After decomposition, images $I_{mod,ij}$ is obtained by removing one of the generated IMFs (IMFij containing most noisy components).

$$I_{mod_{ij}} = I - IMF_{ij}$$

The reconstructed images are smoothed by Frost filter [9] as,

$$I_{ij}^{F} = Frost(I_{mod_{ij}})$$

The filter is adaptive. It preserves both edges and features. It is also effectively used for speckle reduction in SAR and holographic images [10, 11]. The result will be a smoothened image.

III. RESULT ANALYSIS

The comparison is done on different methods BEMD, BEMD + FROST, MBEMD and MBEMD + FROST. For this, images with different formats are taken. Result is analyzed based on the PSNR value of the output image. The comparison is tabularized and is given in Table 1.

Table 1. Comparison table using PSNR

IMAGE	PSNR			
	BEMD	BEMD + FROST	MBEMD	MBEMD + FROST
Lena (Png)	26.4256	31.4701	26.7908	32.435
Cyst (Jpg)	25.0155	32.568	25.5035	32.6596
Lena (Jpeg)	23.0847	29.872	23.5039	29.8894
Cyst (Dicom)	20.8141	30.1129	21.1017	30.0886

In this comparison, BEMD+FROST produce good image quality and PSNR than BEMD method. Similarly, MBEMD+FROST produce good image quality and PSNR than MBEMD method.
From this, it is clear that, better result is obtained by using MBEMD and MBEMD + Frost than by using BEMD and BEMD+FROST.

IV. CONCLUSION

Speckle noise in ultrasound images has very complex statistical properties which depend on several factors. The methods discussed in this paper aims at reducing the speckle noise in the ultrasound images. The comparison result shows better result is obtained from using MBEMD along with frost filter.
This study will be helpful to the beginners and researchers in the area of digital holography. Since it gives a better visualization effects after denoising and smoothening, it opens the possibility to implement in several applications.Authors and Affiliations

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