An Adaptive Fractional Calculus Image Denoising Algorithm in Digital Reflection Dispensation

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Abstract— Image de-noising has become an important step in digital image processing and removing unwanted noisy from the image is important area of the research. The project assign to generate the noise free images from the noisy images has consider the three objective which are (1) suppression of the noise effectively in uniform regions, (2) preserve edges and other similar image characteristics and (3) provide a visually natural appearance. In this project the hybrid nature of technique is used which include fractional order for determination diffusion coefficients and a residual error term and wavelet transform method for decomposition of images into low and high frequency. The diffusion coefficients can be used effectively for noise removal and the residual error term can help to prevent image distortion. In this project simulated performance of the image de-noising are done using MATLAB and peak signal-to-noise ratio (PSNR), Normalized Cross Correlation (NCC), Normalized Absolute Error (NAE) and Structural Content (SC) are used to evaluate the method.

Keywords: Generalized fractional operator, interpolation, filter mask, image denoising, texture

I. INTRODUCTION

The development of information technology and the rapid growth of computer networks allowed large files, such as digital images, to be easily transmitted in open networks such as the internet. Transmission from one place to another place affect the images. Due to the transmission channel noise associated with images. Images play a very important role in many fields such as astronomy, medical imaging and images for forensic laboratories. Images used for these purposes have to be noise free to obtain accurate results from these images. Processing of this type of noisy images are required and the method for removing the noise from the images is called Image de-noising [1]. Image de-noising has become an important step in digital image processing and removing unwanted noisy from the image is important area of the research. The image de-noising algorithms have to remove the unwanted noisy elements and keep all the relevant features of the image [2]. The image de-noising algorithms have to tradeoff between the two parameters i.e. effective noise removal and preservation of image details. Image de-noising method is different from image enhancement. As Gonzalez and Woods [3] explain, image enhancement is an objective process, whereas image de-noising is a subjective process. Image de-noising is a restoration process, where attempts are made to recover an image that has been degraded by using prior knowledge of the degradation process. Image enhancement, on the other hand, involves manipulation of the image characteristics to make it more appealing to the human eye. There is some overlap between the two processes.

II. INTRODUCTION TO DIGITAL IMAGE PROCESSING

The term digital image processing generally refers to processing of a two-dimensional image by a digital computer. A digital image is an array of real or complex number represented by a finite number of bits used for digital image processing and in this finite number of elements, each of which has a particular location and value. These elements are referred to as picture elements, image elements, pel's, and pixels. Pixel is the term most widely used to denote the elements of a digital image [2]. An image may be defined as a two-dimensional function f(x, y) where x and y are spatial (plane) coordinates and the amplitude of at any pair of coordinates (x, y) is called the intensity or gray level of the image at that point. When x, y and the amplitude values of f are all finite discrete quantities the image is called digital image.

Digital image processing methods has a broad spectrum of principal applications, such as

- Remote sensing via satellites and other spacecraft's.
- Image transmission and storage for business applications.
- Medical processing, radar, sonar and acoustic image processing.
- Robotics and automated inspection of industrial parts.

Image processing typically attempts to accomplish following basic classes of problems [3]

- Image representation and modeling is the fidelity or intelligibility criteria for measuring the quality of an image or the performance of a processing technique.
- Image enhancement the process of improving the quality of a digitally stored image by manipulating the image and alters the image to makes its meaningful clearer to human observer.
- Image restoration is concerned with filtering the observed image to minimize the effect of degradations.
- Image analysis is concerned with making quantitative measurements from an image to produce a description of it and it involves the study of feature extraction, segmentation and classification techniques.

III. TECHNIQUES OF IMAGE ENCRYPTION

Figure 1 shows the block diagram of image de-nosing process. In proposed method fractional derivative and wavelet transform are used for pre-filtering and decomposition. In this method only soft and hard thresholding methods are used. In this work 3 level wavelet decomposition is used during decomposition and reconstruction [2, 5].

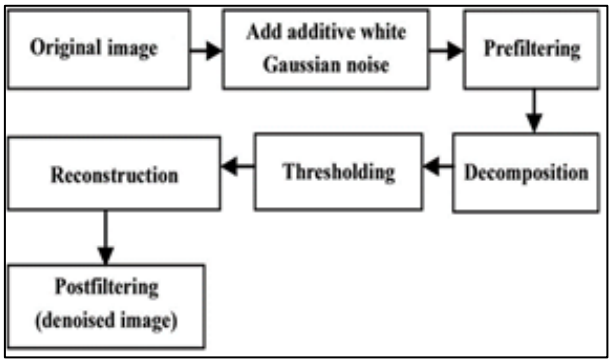


Fig. 1: Block diagram of image de-nosing process

A. *Noise Sources*

The Image is made of millions of tiny light-sensitive components called pixel. This pixel is made by sensor acquired data. This data fluctuates in their physical, electrical, and optical properties, which employed the independent noise (termed as dark current shot noise) into the acquired image. Another source of the shot noise is the photon shot noise. Photon detected from the various angle of the sensor create the photon noise. Strengthening of the sensor signal also increase the noise power which adds amplification noise in nature of Gaussian distribution. The Analog to digital convertor also employed the thermal as well as quantization noise due to the quantization and sampling the method. Due to the quantization signal is rounding off to the quantized level and occurred because there are only a finite number of bits to represent the intermediate floating point results during computations [6]. Basic blocks of the source of noise of digital camera is shown in figure 2.

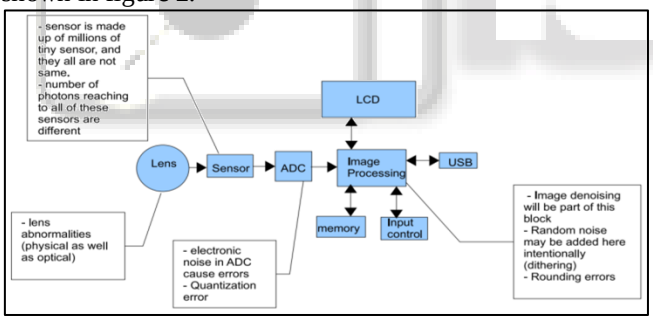


Fig. 2: Permutation of rows and columns [6]

B. *Prefiltering*

Pre-filtering techniques to improve rate distortion performance and subjective quality for noisy input signals. In this work fractional derivative techniques are used as pre-filtering process. The fractional derivative improves the high-frequency (HF) portion of signal while increasing the order of the fraction derivative frequency of the signal also increase in nonlinear rapid growth. At the same time, fractional differential reserves the low-frequency (LF) portion of signal also at certain degree non-linearly. With the increasing order and frequency of fractional differential, the attenuation gradually increases. Therefore, fractional integral has image de-noising effect, whereas fractional differential enhances and preserves image edge and texture [7].

C. *Decomposition*

Decomposition is used in this work for processing of the images. Various transformation methods are used for decomposition method. Laplacing pyramid transform, Discrete cosine transform, wavelet transform are the basic decomposition method used in image processing method. Decomposition are used for transformation of the images into the various frequency level. In this work wavelet transform is used for decomposition of the images into various level. The other properties of the wavelet transform that help in the image de-noising are sparseness, clustering, and correlation between neighboring wavelet coefficients [8]. The wavelet coefficients of natural images are sparse. The histogram of the wavelet coefficients of natural images tends to peak at zero.

D. *Thresholding*

These methods use a threshold and determine the clean wavelet coefficients based on this threshold. There are two main ways of thresholding the wavelet coefficients, namely the hard thresholding method and the soft thresholding method [9].

E. *Reconstruction and Postfiltering*

Reconstruction is the inverse decomposition method for generating the de-noised images. After decomposition image are filtered and made noise free. After the de-noising reconstructing the image into the same format is necessary for seeing information in same way. Post-filtering is also the invers fraction derivative method which is required to make the frequency information distribution in the equal way.

IV. PROPOSED METHODOLOGY

The proposed model for image de-noising are processed by the given block diagram shown in Figure 3 First the image is represented in a matrix form. Each element of the matrix is representing a pixel and possess the gray value in the range between 0 to 255. Image are mixed with the noise for analysis of the de-noise process. After the noise image are post processed and transformed for de-noising and reconstruction and quality analysis has performed for assessment of the techniques. Each of these steps is described in details by using the flow graph of the proposed method shown in figure 4.

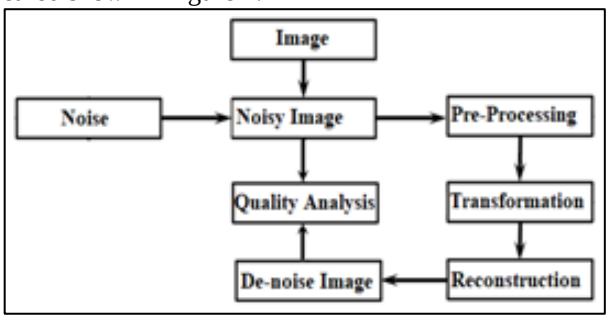


Fig. 3: Block diagram of proposed model

A. *Noise Addition*

The images are acquired by using the various sensor which is noisy in nature due to various source. This noise is in random in nature. For the de-noising process, in this work

noise free images taken as input images and random noise is added into the input noise. For this 40% of the signal amplitude is taken as a reference for generation of random noise and this noise is added into the images.

B. Pre-processing

Pre-processing is the next step for the proposed method in this enhancement of the noise image are performed for easily removal of the noisy signal. For this fractional derivative based transformation is used. Noise signal in a image is in form of high frequency signal. The fractional derivative improves the high-frequency (HF) portion of signal while increasing the order of the fraction derivative frequency of the signal also increase in nonlinear rapid growth. At the same time, fractional differential reserves the low-frequency (LF) portion of signal also at certain degree non-linearly. With the increasing order and frequency of fractional differential, the attenuation gradually increases.

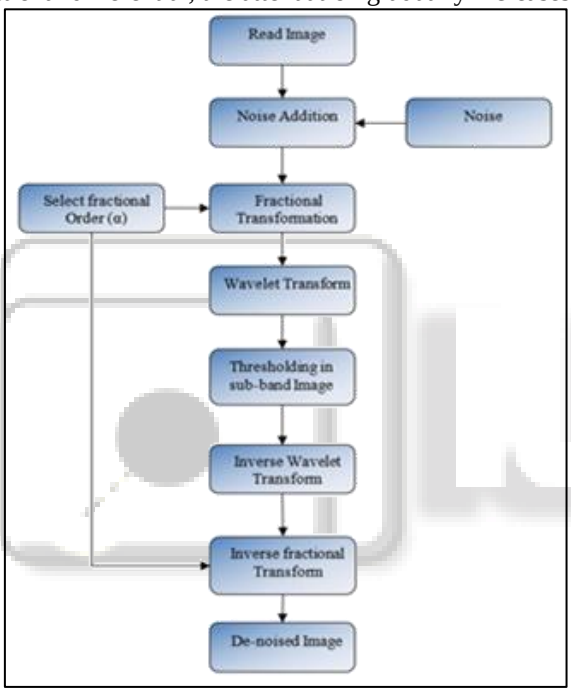


Fig. 4: Steps of image de-noising

C. Transformation

Digital Wavelet transform is used after taking the fractional derivative of the noise image. For this 3 level decomposition and db4 or db2 mother wavelet function are considered.

V. Performance Analysis

In this chapter performance and result analysis of the proposed image Denoising method are assessed. The de-noising method was applied to different images like barbara.jpg, Flower.jpg. cameraman.tif, rice.png, peppers.png and corresponding result for each images are discussed. To evaluate the performance of the whole process are divided into two class one is visibility analysis matrix and second is result analysis.

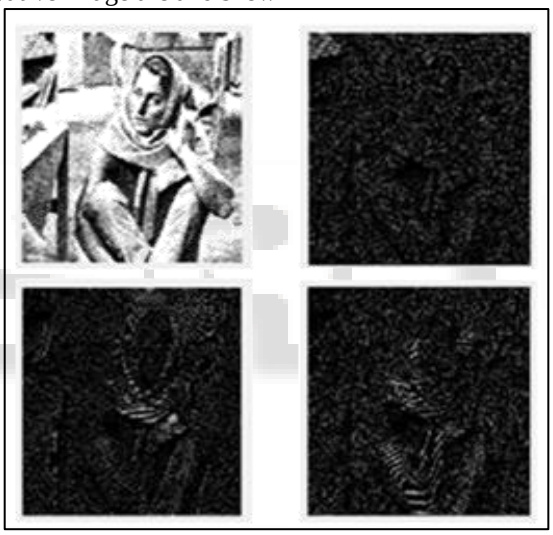
A. Quality analysis

o evaluate the performance of the proposed method various format of reference image considered i.e. jpg, png, tif and noise images (40% amplitude of reference images in random nature) for study. Figure 5 show the reference image and their noise added image.

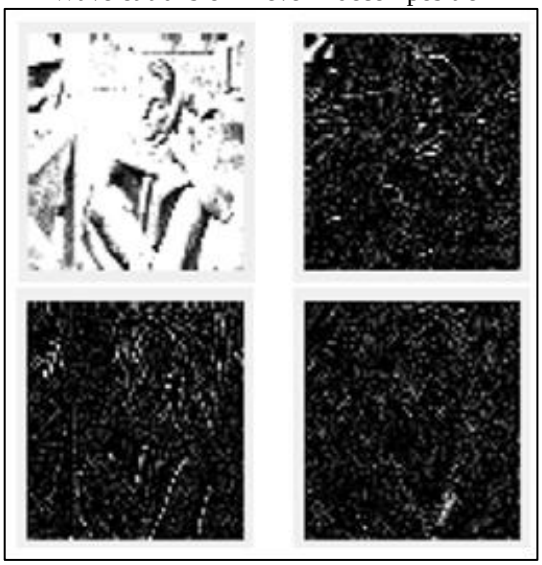
Fig. 5: Set of images for quality analysis of proposed method (a) Reference Image and (b) Noisy Images

1) Performance assessment using wavelet decomposion and denoising

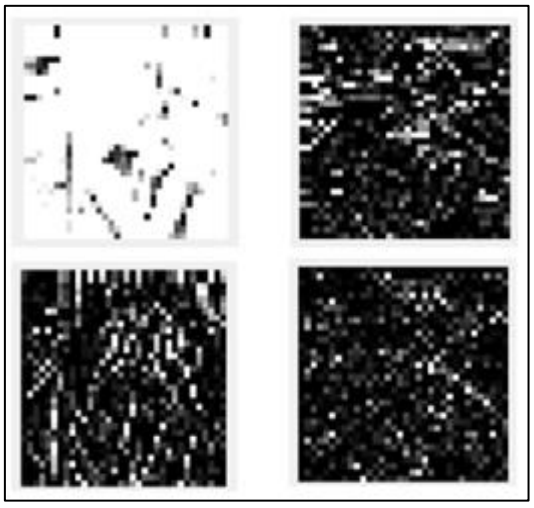
For study of proposed method 3-level wavelet decomposition sub band images sets of the fractional derivative image are and shown



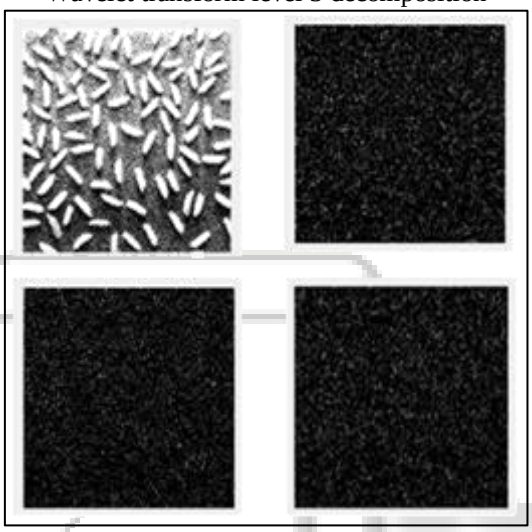
Wavelet transform level 1 decomposition



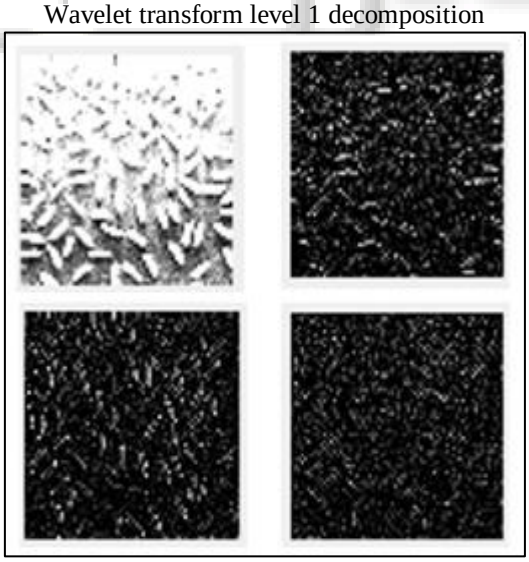
Wavelet transform level 2 decomposition



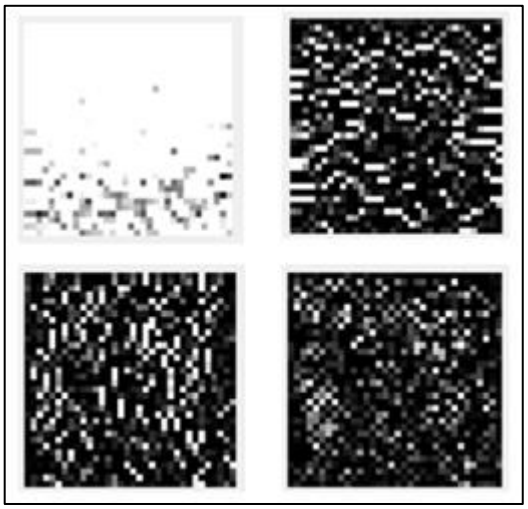
Wavelet transform level 3 decomposition



Wavelet transform level 1 decomposition

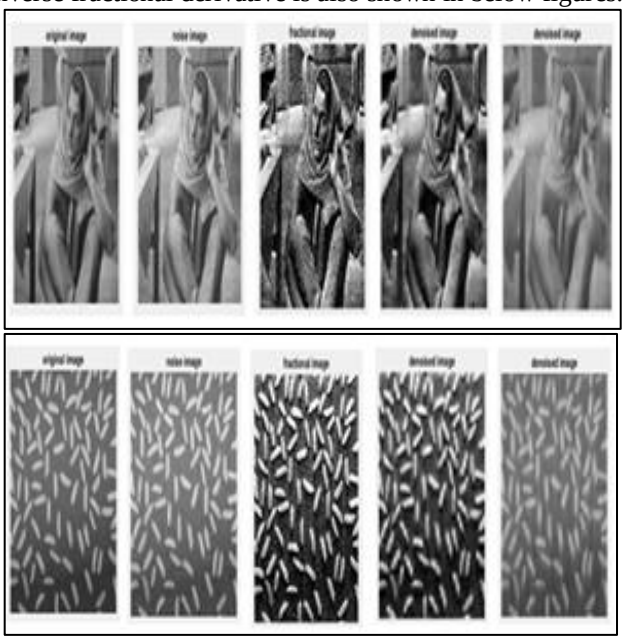


Wavelet transform level 2 decomposition



Wavelet transform level 3 decomposition

However, the performance of the proposed method can determine by quantity parameter analysis but as time by seeing the output result it is also possible to find out the performance of the method below figures shows the set of input images, noisy images, fractional derivative of the noisy images, de-noised wavelet decomposed images and de-noised images. The fractional derivative improves the high-frequency (HF) portion of signal while increasing the order of the fraction derivative frequency of the signal also increase in nonlinear rapid growth. At the same time, fractional differential reserves the low-frequency (LF) portion of signal also at certain degree non-linearly. Hence, the advantages of fractional derivative are utilized in proposed method. After that wavelet decomposition is applied to the images and soft thresholding method is applied in decomposed vertical, horizontal and diagonal components and the de-noised images before and after the inverse fractional derivative is also shown in below figures.



Set of image (a) reference (b) noisy (c) fractional noisy (d) Wavelet decomposed de-noised (e) de-noised

B. Assesment using Quantity analysis parameter

1) Peak Signal to Noise Ratio (PSNR):

PSNR is the ratio between the maximum possible power of a signal and the power of corrupting noise that affects the fidelity of its representation. Because many signals have a very wide dynamic range, PSNR is usually expressed in terms of the logarithmic decibel scale [25,26].

For reference image (I) and output image (O) with same dimension N×M by E_{rr} and $PSNR$ can calculated by

$$E_{rr} = \frac{(I-O)^2}{M \times N} + E_{rr} \qquad (5.1)$$

$$PSNR = 10 \log_{10}\left(\frac{255^2}{E_{rr}}\right) \qquad (5.2)$$

A higher value of PSNR shows the output image is accurate and same as reference images. High value of the PSNR also define the signal strength is more as compare to the noise signal. For analysis PNSR are obtained for noisy and de-noised images with respect to the reference images and shown in Table5.1. The results can illuminate that our proposed algorithm is efficient and able to reduce the noise in image. As can see in results PSNR of the de-noise image increases by 1.5 time the PSNR of the noisy image.

S. No.	Images	Noisy image	De-noised image
1	barbara.jpeg	20.88	33.83
2	Rice.png	20.86	32.07

Table 5.1: PSNR of noisy and desoinsy images with respect to the reference image

2) Normalized Absolute Error:

These parameter is similar as MSE, but have subtle difference in the outcomes which makes the use normalized Absolute errors (NAE) in order to get a better decision of error to evaluate picture quality objectively. NAE define as:

$$NAE = \frac{\sum_1^M \sum_1^N (|I-O|)}{\sum_1^M \sum_1^N (|I|)} \qquad (5.3)$$

A higher NAE value shows that image is of poor quality. For analysis NAE are obtained for noisy and de-noised images with respect to the reference images and shown in Table 5.2. From the results it is clear that the NAE of the de-noised images is very low near to zero. This shows the quality improvement in de-noised image.

S. No.	Images	Noisy image	De-noised image
1	barbara.jpeg	0.18	0.024
2	Flower.jpg	0.19	0.027
3	Rice.png	0.18	0.04

Table 5.2: NAE of noisy and desoinsy images with respect to the reference image

3) Normalized Cross Correlation:

Similarity between the two images can be calculated by using cross correlation and this is normalized between the 0 to 1 for comparative analysis and Normalized cross-correlation is define as:

$$NCC = \sum_1^M \sum_1^N \frac{(I \times O)^2}{I^2} \qquad (5.4)$$

Value of NCC near to one shows the high percentage of the matching of images lower (near to zero) value of NCC shows the de-similarity between the images. For analysis NCC are obtained for noisy and de-noised images with respect to the reference images and shown in Table 5.3. From the results it is clear that the NCC of the de-noised images is near to one, which shows the highest correlation between the two images. Hence, the proposed method are capable for de-noising the noisy images.

S. No.	Images	Noisy image	De-noised image
1	barbara.jpeg	1.15	1
2	Rice.png	1.16	1

Table 5.3: NCC of noisy and desoinsy images with respect to the reference image

4) Structural Content:

The Structural Content (SC) calculated the information ratio between the input and output images and define as:

$$NCC = \sum_1^M \sum_1^N \frac{(I \times O)^2}{I^2} \qquad (5.5)$$

Higher value of SC shows the good quality of images. For analysis SC are obtained for noisy and de-noised images with respect to the reference images and shown in Table 5.4. From the results it is clear that the SC of the de-noised images is near to one, which shows the high similarity between the two images. Hence, the proposed method is capable for de-noising the noisy images.

S. No.	Images	Noisy image	De-noised image
1	barbara.jpeg	0.75	1
2	Rice.png	0.74	1

Table 5.4: SC of noisy and desoinsy images with respect to the reference image

VI. Conclusion

In this project the hybrid combination of fractional and wavelet transform is used for proposed techniques. Fractional order is used for enhancing the information intensity of the high frequency signal without losing the low frequency information. Noise present in images contents the high frequency information. After this in proposed method the wavelet transform method is used which divides the image into the sub-band images. This sub-band images have separate low and high frequency information.

Threshold method filtered the noise signal of the images. After the image denoising it is found that the proposed method has capability to reduce the noise of the image. In this project simulated performance of the image de-noising are done using MATLAB and peak signal-to-noise ratio (PSNR), Normalized Cross Correlation (NCC), Normalized Absolute Error (NAE) and Structural Content (SC) are used to evaluate the method. From the results it is found that the proposed method is improve the PSNR, NCC, NAE and SC.

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