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# IMAGE NOISE REMOVAL WITH EXTENSION TO BM3D

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***Abstract:*** Image denoising techniques developed so far, have shown successful noise reduction results. As far as the results are considered, noise contents are only targeted to show that denoising is successful. After denoising most of the time as most pixel values are approximated to their neighboring pixels for denoising, image sharpness and appearance is altered up to considerable extent. Hence after denoising if image enhancement in terms of its resolution is required, then obtained results can show that quality is enhanced and quality is up to nearer to noiseless image even after noise reduction from noisy image. This paper indicates the combined approach of denoising and resolution enhancement followed by existing retinex technique for better presentation quality of image. The results obtained show that quality is better in terms of PSNR.

***Key Words:*** ***Image denoising, BM3D, CFA, SAPCA, debluring, resolution enhancement, retinex.***

## 1. INTRODUCTION

In human perception, vision plays most important role. Thus the field of digital image processing has widest range of applications. Image display and analysis are mostly dependent on quality of image obtained. There are varieties of causes which are responsible for degradation of image quality. Thus there is immense need of image enhancements with respect to their applicability. With the set goal of accentuation of certain images along with suppressing the irregularities in terms of noise present in images, the enhancement is needed for certain image features for subsequent analysis or for image display [1]. Examples include contrast and edge enhancement, pseudo coloring, noise filtering, sharpening and magnifying. As far as visual information is concerned, the image quality is mostly important, at least for quality display, in terms of its resolution as a measure. The enhancement process itself is interactive and application oriented [1]. Also the inherent information displayed in the images is not increased by simply one type of enhancement technique. One technique simply emphasizes certain specified image characteristics, and combined approach of two or more techniques is ultimately responsible for enhancement of visual quality. Resolution of an image has been always an important issue in many image- and video-processing applications, such as video resolution enhancement [2], feature extraction [3], and satellite image resolution enhancement [4]. Image resolution enhancement using wavelets is a relatively new subject and recently many new algorithms have been proposed [5]–[11]. Carey et al. have estimated the details of wavelet coefficients in order to improve the sharpness of the reconstructed images [5]. Their technique was carried out by investigating the

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evolution of wavelet transform extrema among the same type of sub bands. Edges identified by an edge detection algorithm in lower frequency sub bands were used to prepare a model for estimating edges in higher frequency sub bands and only the coefficients with significant values were estimated as the evolution of the wavelet coefficients. In many researches, hidden Markov has been also implemented in order to estimate the coefficients [12]. Cycle Spinning based image resolution enhancement technique can provide better results compared t earlier results but implementation is quite complex in nature which may consume more time for providing the output. The comparative study is also indicated in [12] for selecting the technique on the basis of outputs obtained.

An important consideration in image representation is the fidelity or intelligibility criteria for measuring the quality of an image or the performance of processing technique. The well known technique for image improvement at the time of display is retinex. In the computer graphics and imaging world, most display devices are linearized to achieve correct reproduction of intensity [13,14]. In the course of experimentations, it can be noted that this commonly accepted linear representation often fails to produce a realistic rendition of the observed scene. The images either have saturated bright regions to compensate for the dark regions, or clipped dark regions to compensate for the bright regions. Even when the dynamic range of the scene is narrow enough to be completely captured by the dynamic range of the imaging device, the resultant image is a poor representation of the observed scene, being too dark and too low in overall contrast. When image resolution enhancement is done representation is most important factor which is responsible for better visual quality of the scene. Retinex method have proved to be better technique in such approach which can be reused along with other image enhancement technique we use in this paper.

This paper proposes a combined approach for image enhancement predefined earlier along with newly added debluring and proposed wavelet based image resolution enhancement technique[22]. Along with this introduction as platform of proposed work section II indicates the techniques used for image enhancement which constitutes existing block matching and 3D filtering (BM3D) method for noise removal, wavelet based new proposed technique for image resolution enhancement and existing retinex as a technique for image display improvement. Section III indicates the experimentation and results followed by conclusion in section IV.

## 2. PROPOSED WORK

Image enhancement is done along with consideration of combined techniques for noise removal, resolution enhancement and representation. The proposed work constitutes image denoising as first stage, proposed wavelet based resolution enhancement as second stage and retinex as final stage for improvement in representation of processed image.

Figure 1 indicates the stages followed for image enhancement approach.

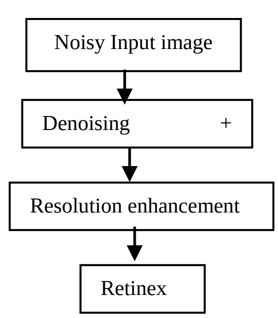



Figure1: Stages of image enhancement

### *2.1 Noise removal and debluring:*

For image denoising variety of techniques are indicated in number of papers. Out of which we consider the BM3D technique as best performing method for image denoising as indicated by Kostadin Dabov et al. [15]. The experimental results indicated in the paper show that the BM3D method delivers good denoising performance. Along with BM3D if color filter array (CFA) is combined to remove camera sensor noise then results obtained are also good [16]. Each cell of sensor records one color value, missing color components at each position are interpolated from the available CFA sensor readings to reconstruct the full-color image in camera. The color interpolation process is usually called color demosaicking (CDM) [17]. BM3D based image denoising can also be combined with Shape Adaptive Principle Component Analysis (SAPCA) to improve noise removal.

Mostly denoising is consisting of some noise representing pixels value replacement method. Due to which the processed image appears as blur compared to sharp images. Image sharpness depends on the quality of pixels in and total number of pixels representing the image in terms of high and low frequency components. These high and low frequency components can be processed to obtain better image resolution to improve the image quality compared to the resulting image from denoising process.

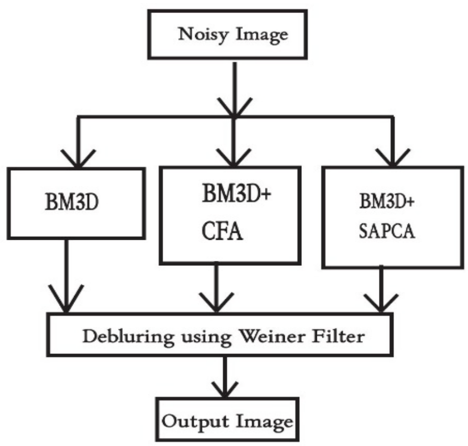



Figure 2: Denoising and debluring

### *2.2 Resolution Enhancement:*

The stages involved in resolution enhancement are as shown in figure 2.For enhancing the image in terms of the resolution, high and low frequency decomposition is done using discrete wavelet transform (DWT) with ‘haar’ features.

The image is decomposed in four parts LL, LH, HL and HH. The resulting decomposition is as shown in figure 3. Each decomposed frequency component is further processed separately using interpolation which increases the number of pixels in particular frequency components of the image. Interpolation has variety of types out of which ‘bicubic interpolation’ is used to enhance the contents of particular frequency components in terms of number of pixels representing it.

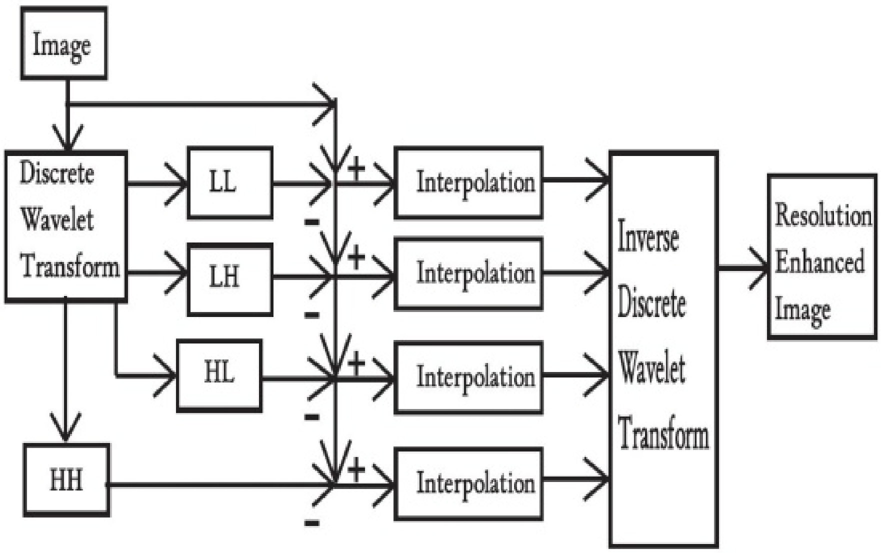



Figure 3: Proposed Image resolution enhancement


Figure 4: decomposition of image using DWT

The output of interpolation is further combined with other frequency components interpolation results using inverse DWT (IDWT). The outcome of this is final resolution enhanced image. Even after resolution enhancement, as discussed earlier, due to in sufficient dynamicity of displays image representation plays most important role which if further achieved by existing retinex method.

## 2.3 Retinex:

The multiscale retinex method is represented by the equation shown below.

$$R_i(x_1, x_2) = \sum_{k=1}^{K} W_k\{\log I_i(x_1, x_2) - \log[F_k(x_1, x_2) * I_i(x_1, x_2)]\} \; i = 1, \ldots N,$$

…..equation (1.1)(courtesy [17])

where index i references the i'th spectral band, (x1 ,x2) is the pixel location in Cartesian coordinates, and * is the convolution operator. N is the number of spectral bands N51 for grayscale images, and N53, iPR, G, B for typical color images. I is the input image and R is the output of the MSR process. Fk is the k'th ~Gaussian! surround function, Wk is the weight associated with Fk , and K is the number of surround functions, or scales. The Fk are given as:

$$\mathrm{F_k}(x_1, x_2) = Kexp[-(x_1^2 + x_2^2)/\sigma_k^2] \quad \text{...equation(1.2)(courtesy [17])}$$

where, σk are the standard deviations of the Gaussian surrounds. The magnitude of σk controls the extent of the surround: smaller values of σk result in narrower surrounds. The MSR output is normalized by k. The MSR reduces to the single scale retinex,when K=1, with the additional constraint that W1=1.

## 3. EXPERIMENTAL RESULTS

For performance evaluation of combined approach of proposed method, experimentation is done using MATLAB. The pseudo code for the implemented algorithms is detailed as:

**Pseudo Code of processing steps:**

*Step 1: Take input image*

*Step2: Add salt and pepper noise*

*Step3: Remove noise by BM3D method and deblur using Weiner filter*

*Step4: Enhance resolution of image obtained from step3 by using proposed image resolution enhancement method*

*Step5: Perform retinex processing on image obtained from step4*

*Step6:Perform analysis on obtained result.*

Table 1: Comparative results of noise removal and debluring

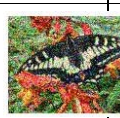
| **Input Image** | **Noisy** | **BM3D+Debluring** | **BM3D+CFA+Debluring** | **BM3D+SAPCA+Debluring** |
|---|---|---|---|---|
|  |  |  |  |  |
|  |  |  |  |  |

Table 1 indicates the results of the input images for noise removal and debluring. Table 2 indicates the BM3D and CFA and SAPCA based noise removed along with debluring and Resolution enhancement after BM3D and retinex output.

Table 2: Resolution enhancement and retinex comparison

| **BM3D+CFA+Debluring** | **BM3D+SAPCA+Debluring** | **BM3D+Debluring+Resolution Enhancement+Retinex** |
|---|---|---|
|  |  |  |
|  |  |  |

The PSNR and MSE analysis is done on the results obtained. Table 3 indicates the PSNR values obtained for proposed and existing methods and table 4 shows the results for mean square error (MSE) calculations.

Table3: PSNR Analysis of Images using improved strategy

| **Image** | **Size** | **BM3D** | **BM3D+ Enhancement** | **BM3D+ Enhancement+ Retinex** | **BM3D+ CFA** | **BM3D+SAPCA** |
|---|---|---|---|---|---|---|
| Butterfly | 256x256 | 22.49 dB | 32.35 dB | 45.66 dB | 28.26 dB | 31.33 dB |
| Satellite | 512x512 | 23.45 dB | 34.25dB | 47.68 dB | 32.23 dB | 33.12 dB |

Table4: MSE Analysis of images using improved strategy

| **Image** | **Size** | **BM3D** | **BM3D+ Enhancement** | **BM3D+ Enhancement+ Retinex** | **BM3D+ CFA** | **BM3D+SAPCA** |
|---|---|---|---|---|---|---|
| Butterfly | 256x256 | 753.14 | 663.35 | 610.52 | 742.30 | 733.12 |
| Satellite | 512x512 | 711.76 | 612.88 | 570.32 | 685.14 | 680.31 |

## Annotations:

It can be seen that from the results obtained as shown in figure from three methods BM3D+Debluring+enhancement+retinex method out performs in terms of better results. As CFA is applicable to mostly the cameras with array of filters structure for capturing color images, CFA is only considerable for low cost devices. SAPCA though provides better image quality, the representation gets significantly affected in terms of contrast information.

## 4. CONCLUSION

BM3D Method gives better results of noise removal compared to other noise removing methods but shows shortfall in terms of blur effect.Thoughthe noise is removed image resolution and sharpness is affected. Debluring is applied after BM3D to improve sharpness. The proposed method applied on BM3D output images and resolution is sufficiently enhanced and hence shows improvement in quality compared to BM3D output. Retinex output is also responsible in terms of effective presentation of the image. We also compared the outputs of CFA and SAPCA used with BM3D to that of our method. Comparison shows satisfactory results. Theoutput of each stageis compared in terms of PSNR and MSE calculations which also indicates that proposed method is responsible for improvement of image quality.DCT based debluring effect can improve the performance even further which is to be analyzed in future.

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