Image Enhancement using Hybrid Filtering Technique

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Abstract: ***Digital Image Processing involves the modification of digital data for improving the image qualities with the aid of computer. The processing helps in maximize the clarity, sharpness of image and details of features of interest towards the extraction of information and further analysis. The digital image is given as input into a computer and computer is programmed to change these data with the help of an equation or with series of equations and then store the values of the computation for each pixel or picture element. Noise in the digital image is a basic problem. Noise is defined as unwanted signals. There are different filters to remove single type of noise such as salt and pepper, speckle noise, Gaussian noise etc. But if the image is corrupted by mixed type of noise then these filters not remove the noise exactly, so we design a Hybrid filter which is composite of different filters to remove mixed type of noise from digital image.***

Keywords: Noise Models, Hybrid Filter, PSNR, MSE

1. Introduction

Images are often corrupted with noise during the acquisition of image, during transmission of image, and retrieval from any storage media. While photograph taken with a digital camera under low lighting conditions many dots can be spotted in a Photograph .Noise in digital image often occurs during the acquisition of image due to Sensor (e.g., thermal or electrical interference) and Environmental conditions (rain, snow etc.). Most natural images are assumed to be corrupted by Gaussian Noise, Salt and Pepper Noise and image Blur ness, Impulse Noise etc. There are many approaches to deal with single type of noise such as Gaussian noise in natural images. Virtually all the classic noise removal method is based on a simple model of the noise. Typically they assume the noise to be single type of noise. Although Different type of filters are used for efficient noise reduction ability, but still have problem to reduce mixed type of noise from noisy image. We investigate the problem of image enhancement when the source image is corrupted by Speckle noise Gaussian noise, Poisson noise, Salt and Pepper noise, and blurrness, corruption of edges of image which is assumption for the images obtained through scanning, transmitting, compression. We propose an efficient and simple algorithm named Hybrid Filter based on the Curvelet Transform threshold for image denoising, Median Filtering and Unsharp Masking Filter.

2. Noise Models

There are mainly two types of noise:

- **Spatially Independent Noise**
- **Spatially Dependent Noise**

In Spatially independent noise, there are Gaussian noises, impulse (salt and pepper noise). Periodic noise is an example of spatially dependent noise. It is not part of the ideal signal and may be caused by a wide range of sources, Examples are variations in the environmental variations, sensitivity nature of detector, transmission or quantization errors, the discrete nature of radiation, etc. There may be also possible to treat irrelevant scene details as if they are image noise such as surface reflectance textures. The noise characteristics depend on its source, as does the operator which used for best reduces its effects. Many digital image processing packages contain operators which are used to artificially add noise to an image. Purposely corrupting an image with the noise allows us to test resistance of an image processing operator to noise and we can assess the performance of different noise filters.

Uniform Noise

The uniform noise cause by quantizing the pixels of image to a number of distinct levels is known as quantization noise. It has approximately uniform distribution. In the uniform noise the level of the gray values of the noise are uniformly distributed across a specified range. Uniform noise can be used to generate any different type of noise distribution. This noise is often used to degrade images for the evaluation of image restoration algorithms. This noise provides the most neutral or unbiased noise [1].

Uniform noise:

$$p(z) = \begin{cases} \frac{1}{(b-a)} & \text{if } a \le z \le b \\ 0 & \text{otherwise} \end{cases}$$

$$\mu = (a+b)/2; \qquad \sigma^2 = (b-a)^2/12$$

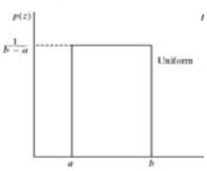


Figure 1.1: PDF, mean, variance of uniform noise

Gaussian Noise or Amplifier Noise

This noise has a probability density function [PDF] of the normal distribution. It is also known as Gaussian distribution. It is a major part of the read noise of an image sensor that is of the constant level of noise in the dark areas of the image [1].

Gaussian noise:

$$p(z) = \frac{1}{\sqrt{2\pi}\sigma} e^{-(z-\mu)^2/2\sigma^2}$$

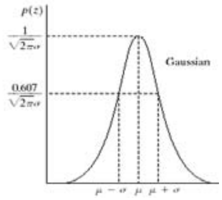


Figure 1.2: PDF of Gaussian Noise

Salt and Pepper Noise

The salt-and-pepper noise are also called shot noise, impulse noise or spike noise that is usually caused by faulty memory locations, malfunctioning pixel elements in the camera sensors, or there can be timing errors in the process of digitization .In the salt and pepper noise there are only two possible values exists that is a and b and the probability of each is less than 0.2.If the numbers greater than this numbers the noise will swamp out image. For 8-bit image the typical value for 255 for salt-noise and pepper noise is 0 [1].

Impulse noise:

$$p(z) = \begin{cases} P_a & for \quad z = a \\ P_b & for \quad z = b \\ 0 & otherwise \end{cases}$$

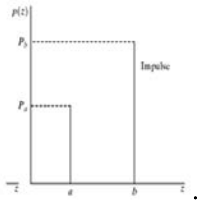


Figure 1.3: PDF of Impulse Noise

Rayleigh Noise

Radar range and velocity images typically contain noise that can be modeled by the Rayleigh distribution [1].

Rayleigh noise:

$$p(z) = \begin{cases} \frac{2}{b}(z-a)e^{-(z-a)^2/b} & for \quad z \geq a \\ 0 & for \quad z < a \end{cases}$$

$$\mu = a + \sqrt{\pi b / 4}; \qquad \sigma^2 = \frac{b(4-\mu)}{4}$$

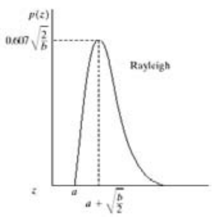


Figure 1.4: PDF, Mean, Variance of Rayleigh Noise

Gamma Noise

The noise can be obtained by the low-pass filtering of laser based images [1].

Erlang (Gamma) noise:

$$p(z) = \begin{cases} \frac{a^b z^{b-1}}{(b-1)!} e^{-az} & for \quad z \geq 0 \\ 0 & for \quad z < 0 \end{cases}$$

$$\mu = b / a; \qquad \sigma^2 = b / a^2$$

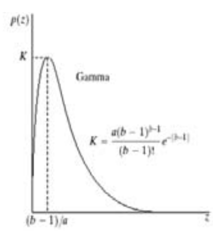


Figure 1.5: PDF, Mean, Variance of Gamma Noise

3. Filters

Filtering in an image processing is a basis function that is used to achieve many tasks such as noise reduction, interpolation, and re-sampling. Filtering image data is a standard process used in almost all image processing systems. The choice of filter is determined by the nature of the task performed by filter and behavior and type of the data. Filters are used to remove noise from digital image while keeping the details of image preserved is an necessary part of image processing.

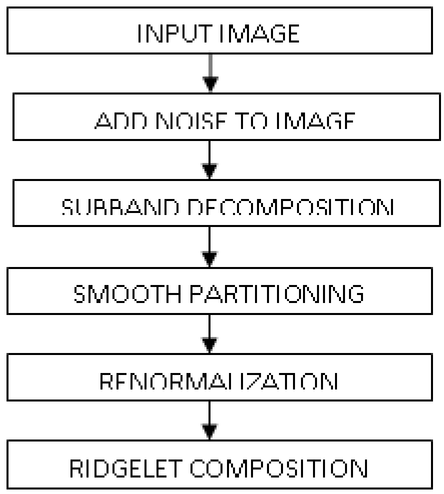
Filter descriptions

g(x, y)=Corrupted image f(x ,y)=Filtered image

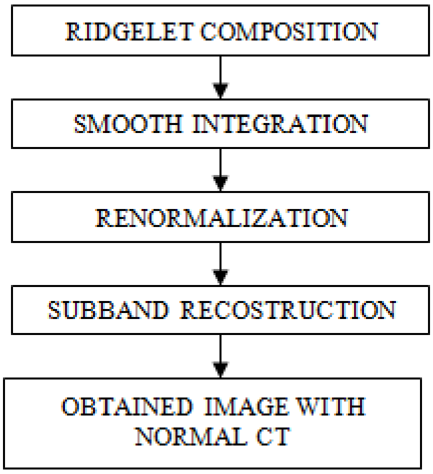
3.1 Curvelet Transformation Filter

The Curvelet transform is a higher dimensional generalization of the Wavelet transform which are designed to characterize the images at different angles and scales. Curvelet Transformation has two unique mathematical properties, which are defined below:

- Curved singularities can be well approximated with very few coefficients and in a non-adaptive manner - hence the name derives "curvelets."
- Curvelets remains coherent waveforms under the action of the wave equation in a smooth medium.



(a)Image Decomposition



(b) Image Reconstruction

Figure 1.6: Flowchart for Curvelet transform processing

3.2 Image Decomposition

3.2.1 Subband Decomposition

The image is filtered into several sub bands in this phase.

$$f \to (P_0 f, \Delta_1 f, \Delta_2 f, \cdots), \quad \text{---- (1)}$$

(a) Divide the image into the resolution layers.
(b) Each layer will contain the details of different frequencies:
P_0 – Low-pass filter.
Δ_1, Δ_2 … – Band-pass (high-pass) filters
(c) We reconstruct the original image from these sub-bands:

$$f = P_0(P_0 f) + \sum_s \Delta_s(\Delta_s f) \quad \text{---- (2)}$$

(d) Low-pass filter Φ_0 deals with low frequencies near $|\xi|\le 1$.
(e) Band-pass filters Ψ_{2s} deals with frequencies near domain $|\xi|\in[2^{2s}, 2^{2s+2}]$.
(f) Go on Recursive construction $-\Psi_{2s}(x) = 2^{4s}\,\Psi(2^{2s}x)$.---- (3)
(g) The decomposition of the sub-bands can be approximated by using the well known wavelet transform. By using the wavelet transform, f is decomposed into S_0, D_1, D_2, D_3, D_4 etc. $P_0 f$ is partially constructed from S_0 and D_1, and may include also D_2 and D_3. $\Delta_s f$ is constructed from D_{2s} and D_{2s+1}.
(h) $P_0\, f$ is "smooth" (low-pass), and can be efficiently represented with wavelet base.

3.2.2 Smooth Partitioning

In this we will dissect the layer into the small partitions. A grid of dyadic squares can be defined as follows:

$$Q_{(s,k_1,k_2)} = \left[\frac{k_1}{2^s}, \frac{k_1+1}{2^s}\right] \times \left[\frac{k_2}{2^s}, \frac{k_2+1}{2^s}\right] \in \mathbf{Q}_s \quad \text{---- (4)}$$

Where Q_s – 4 all the dyadic squares of the grid .
(a) Let assume the w be a smooth window function with 'main' supported of the size $2^{-s}\times 2^{-s}$. For each of these squares, w_Q is a displacement value of w localized near Q. Multiplying $\Delta_s f$ with w_Q ($\forall Q\in\mathbf{Q}_s$) produces a smooth dissection of the function into 'squares'

$$h_Q = w_Q \cdot \Delta_s f \quad \text{---- (5)}$$

The windowing function w is a non-negative smooth function.
(b) Partitioning of the energy:
The energy of certain pixel (x_1,x_2) is divided between all sampling windows of the grid

$$\sum_{k_1,k_2} w^2(x_1-k_1, x_2-k_2) \equiv 1 \quad \text{---- (6)}$$

3.2.3 Renormalization

Renormalization is centering each dyadic square to the unit square $[0,1]\times[0,1]$. For each Q, the operator T_Q is defined below as:

$$(T_Q f)(x_1,x_2) = 2^s f(2^s x_1 - k_1, 2^s x_2 - k_2) \quad \text{---- (7)}$$

Each square which is renormalized by

$$g_Q = T_Q^{-1} h_Q \quad \text{---- (8)}$$

3.2.4 Ridget Analysis

(a) In the ridgelet system each normalized square is analyzed in $\alpha_{(Q,\lambda)} = \langle g_Q, \rho_\lambda \rangle$ ---- (9)
(b) The ridge fragment has an aspect ratio of $2^{-2s}\times 2^{-s}$. After the renormalization, it has localized frequency in band $|\xi|\in[2^s, 2^{s+1}]$.
(c) For representing it a ridge fragment needs only a few ridgelet coefficients.

3.3 Image Reconstruction

The Inverse of the Curvelet Transform:

3.3.1 Ridgelet Synthesis

$$g_Q = \sum_\lambda \alpha_{(Q,\lambda)} \cdot \rho_\lambda \quad \text{---- (10)}$$

3.3.2 Renormalization

$$h_Q = T_Q g_Q \quad \text{---- (11)}$$

3.3.3 Smooth Integration

$$\Delta_s f = \sum_{Q\in\mathbf{Q}_s} w_Q \cdot h_Q \quad \text{---- (12)}$$

3.3.4 Sub-band Recomposition

$$f = P_0(P_0 f) + \sum_s \Delta_s(\Delta_s f) \quad \text{---- (13)}$$

4. Median Filter

Median [2] Filter is a simple and powerful non-linear filter which is based order statistics. It is easy to implement method of smoothing images. Median filter is used for reducing the amount of intensity variation between one pixel and the other pixel. In this filter, we do not replace the pixel value of image with the mean of all neighboring pixel values, we replaces it with the median value .Then the median is calculated by first sorting all the pixel values into ascending order and then replace the pixel being calculated with the middle pixel value. If the neighboring pixel of image which is to be considered contains an even numbers of pixels, than the average of the two middle pixel values is used to replace.

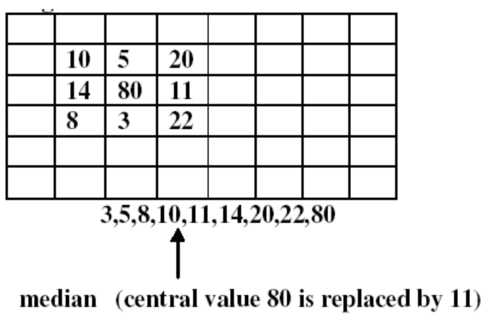


Figure 1.7: Method of Median Filter

5. Algorithm of Median Filter

The algorithm for the median filter is as follows:

Step 1. Select a two dimensional window W of size 3*3. Assume hat the pixel being processed is Cx, y.

Step 2. Compute Wmed the median of the pixel values in window W.

Step 3. Replace Cx, y by Wmed.

Step 4. Repeat steps 1 to 3 until all the pixels in the entire image are processed.

Advantage

1. It is easy to implement.
2. Used for de-noising different types of noises.

Disadvantage

1. Median Filter tends to remove image details while reducing noise such as thin lines and corners.
2. Median filtering performance is not satisfactory in case of signal dependant noise. To remove these difficulties different variations of median filters have been developed for the better results.

6. Unsharp Mask Filter

The unsharp filter uses a simple sharpening operator which derives from its name the fact that it enhances the edges of image and the other high frequency components of an image by a procedure which subtracts smoothed and unsharp version of an image from the original image. The technique of unsharp filtering is commonly used in the printing and photographic industries.

A. Working of Unsharp Masking Filter

Unsharp masking filter produces an image of edge $g(x,y)$ from an input image $f(x,y)$ via

$$g(x,y) = f(x,y) - f_{smooth}(x,y)$$

where $f_{smooth}(x,y)$ is a smoothed version of $f(x,y)$. (See Figure 1.)

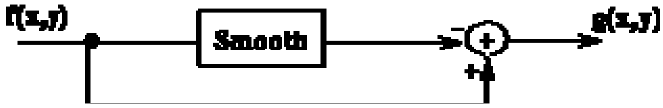


Figure 1.8 Spatial sharpening.

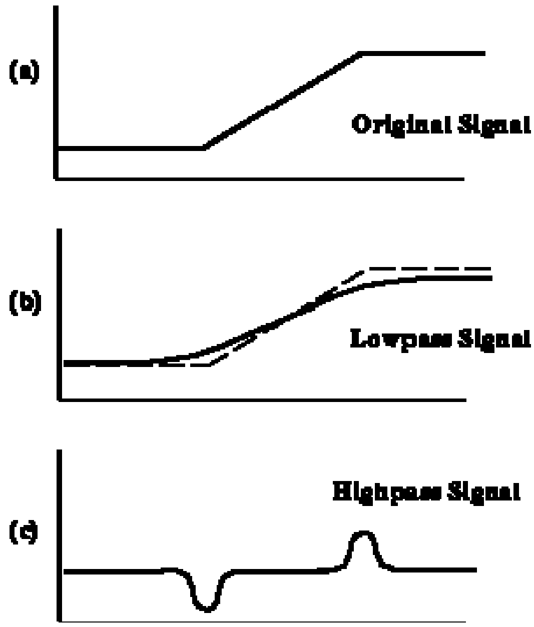


Figure 1.9 Calculating an edge image for unsharp mask filtering.

We can understand the operation of an unsharp mask sharpening filter by the examining its different frequency response via characteristics. Figure 1.9(a) shows about the signal that we have, subtracting away the low-pass components of the signal (as shown in Figure 1.9(b)), yields of the high-pass, or `edge', representation shown in Figure 1.9(c) given below:

This edge image can be used for sharpening edges of an image if we add it back into the original signal, as given in Figure 2.10

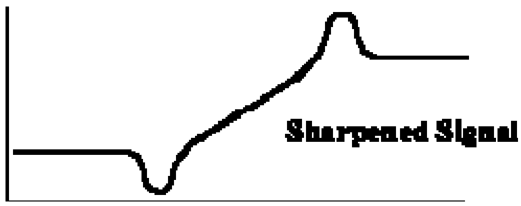


Figure 1.10 Sharpening the original signal using the edge image

Thus, the complete unsharp masking sharpening operator is in Figure 1.11

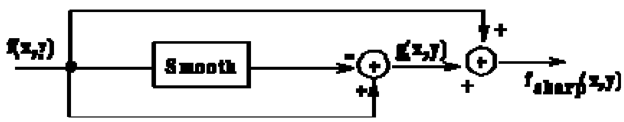


Figure 1.11 The complete unsharp filtering operator.

Now, we can combine all of this into the given below equation:

$$f_{sharp}(x,y) = f(x,y) + k * g(x,y)$$

where **k** is a scaling constant. For **k** the reasonable value vary between the 0.2 and 0.7, in this the larger values providing the increasing amounts of sharpening of edges.

7. Performance Parameters

For comparing original image and uncompressed image, we calculate following parameters:

Mean Square Error (MSE): The MSE is the cumulative square error between the encoded and the original image defined by:

$$MSE = \frac{1}{mn}\sum_{0}^{m-1}\sum_{0}^{n-1}\|f(i,j) - g(i,j)\|^2$$

Where, f is the original image and g is the uncompressed image. The dimension of the images is m x n. Thus MSE should be as low as possible for effective compression.

Peak signal to Noise ratio(PSNR): PSNR is the ratio between maximum possible power of a signal and the power of distorting noise which affects the quality of its representation. It is defined by:

$$PSNR = 20\log_{10}\left(\frac{MAX_f}{\sqrt{MSE}}\right)$$

where MAX_f is the maximum signal value that exists in our original "known to be good" image.

8. Hybrid Filtering

In hybrid filtering scheme, two or more filters are used to filter a corrupted location of a noisy image. The decision to apply a particular filter is based on the noise level of noisy image at the test pixel location and the performance of the filter which is used on a filtering mask.

Proposed Algorithm Steps

Step I: Take noisy image.
Step II: Applying curvelet Transform, Median Filter, Unsharp Mask Filter as under.
1. Applying curvelet Transform as under:
   (a) Sub band decomposition
   (b) Smooth Partioning
   (c) Renormalization
   (d) Redget analysis

2. Applying Median Filter as under:
The algorithm for the median filter is as follows:
Step 1. Select a two dimensional window W of size 3*3. Assume hat the pixel being processed is Cx,y.
Step 2. Compute Wmed the median of the pixel values in window W.
Step 3. Replace Cx,y by Wmed.
Step 4.Repeat steps 1 to 3 until all the pixels in the entire image are processed.

3. Applying Unsharp Mask Filter as under:
a. Unsharp masking produces an edge image $g(x,y)$ from an input image $f(x,y)$ via

$$g(x,y) = f(x,y) - f_{smooth}(x,y)$$

Where $f_{smooth}(x,y)$ is a smoothed version of $f(x,y)$.

b. We can now combine all of this into the equation:

$$f_{sharp}(x,y) = f(x,y) + k * g(x,y)$$

where **k** is a scaling constant. Here **k** reasonable values vary between 0.2 and 0.7, with the larger values providing increasing amounts of sharpening.

Step III: Here Fusion Take place.
In this after combing the result of the two filters that is Curvelet transformation and median filter a fusion image will be resulted.

Step IV: Apply Unsharp Filter in which each edges of image is getting smooth and sharp.

Step V: Reconstruction is taking place, for this take inverse of curvelet transform, by replacing the average pixel value with noisy pixels and smoothing the edges of noisy image.

Step VI: Again fusion take place again with previous fused image and with unsharp mask filter result. After this both filters output finally after removing the all type of noise output is enhanced image

Step VII. Output the final Enhanced image.

9. Flow Chart of Proposed Algorithm

Work Flow for Image Enhancement using Hybrid Filtering Technique that is combination of Curvelet transformation, Median Filtering and Unsharp Mask Filtering:

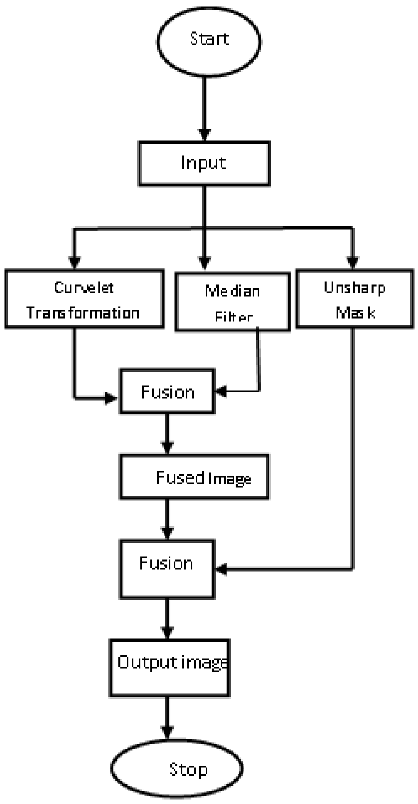


Figure 1.12 Diagrammatic depiction of Proposed Algorithm

10. Simulation Results

This section presents the results of mixed mode filter(Hybrid Filter) that is combination of curvelet transformation, Unsharp mask filter and Median Filter which is applied on to gray scale images as well as on the color images, the images to observe the change in PSNR and MSE ratio. The noisy images are simulated by adding Gaussian noise, Salt and Pepper noise, Speckle noise, Poisson noise on the original images. The performance of the method is illustrated with quantitative performance measure. As quantitative measure the peak signal to noise (PSNR) and MSE is used.

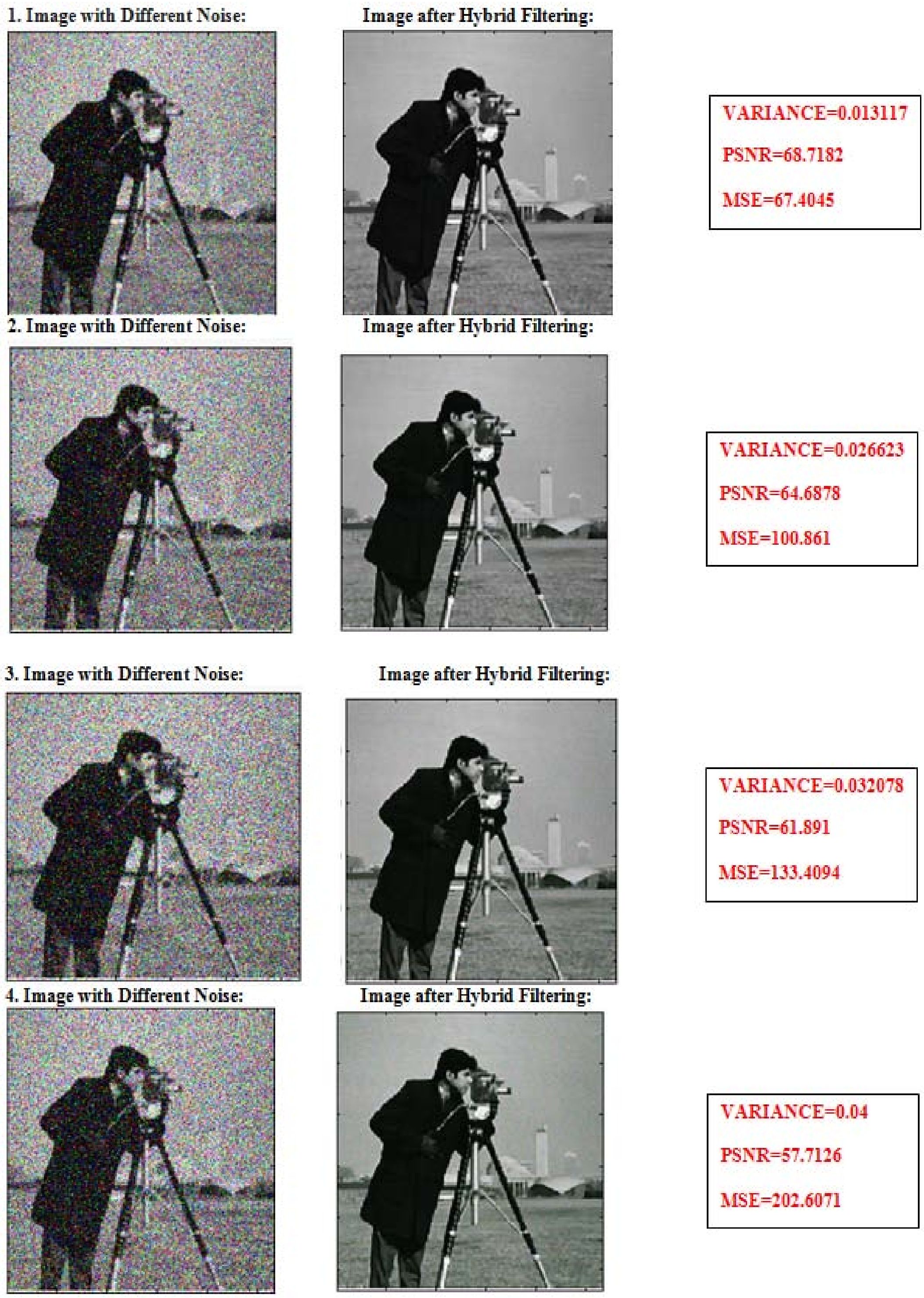


Figure 1.13: Shows the images corrupted with different noise variance are filtered with mixed mode filtering and describe the PSNR and MSE

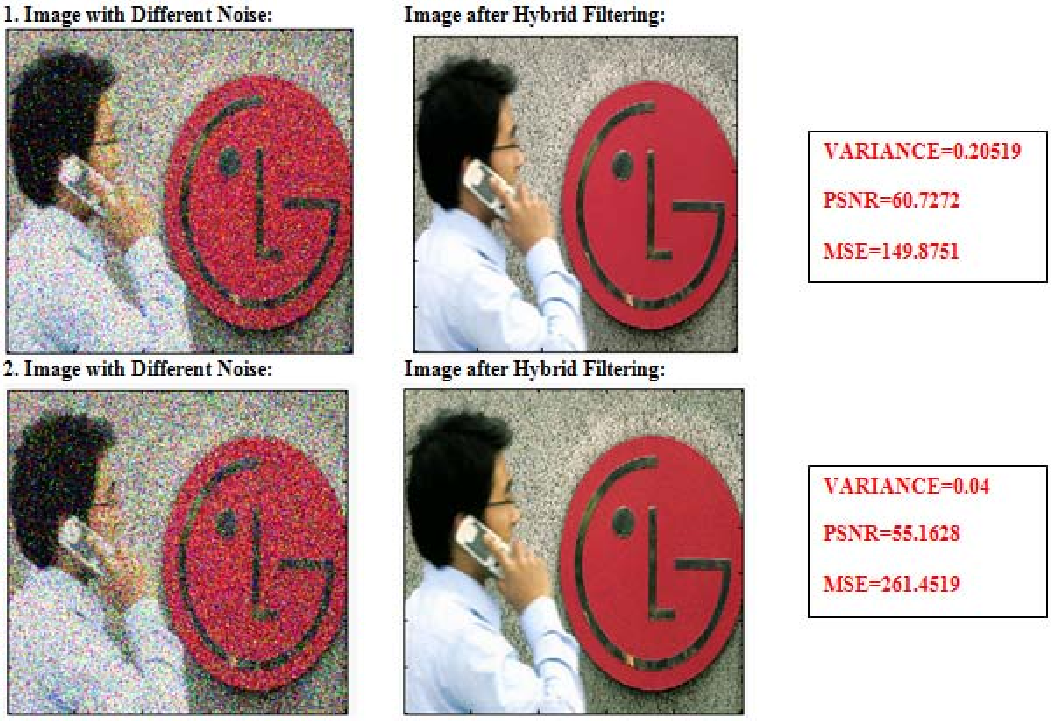


Figure 1.14: Shows the color images corrupted with different noise variance is filter with mixed mode filtering and describe the PSNR and MSE.

11. Conclusion

The proposed method presents the results of Hybrid filter which is combination of the curvelet transformation, Unsharp Mask filter and Median Filter on to the images to observe the change in PSNR ratio and MSE ratio. The noisy images are simulated by adding Gaussian noise, salt and pepper noise, speckle noise and possion noise on the original images. The performance of the method is illustrated with both quantitative and qualitative performance measure. The qualitative measure is the visual Quality of the resulting image. The peak signal to noise ratio (PSNR) is used as quantitative measure. The resulting images after the filtering appear most effective and denoised than the previous noisy image.

12. Scope for Future Work

In future, for the enhancement purpose, images can be taken as from the different application field so that it becomes clearer that for which application which particular technique is better. To get the better result new filtering techniques can be blended with other schemes. So, new parameters can be considered for the evaluation of denoising techniques. Optimization of various denoising techniques can be done to reduce computational complexity as much as possible. Future, for another type of noise based model can be combined and can be used with other denoising scheme and the performance of these methods can be compared.

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