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Performance Analysis of Smoothing Techniques in context with Image Processing

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***Abstract*— Typical flow of an image processing application involve stages like pre-processing, feature extraction and classification or recognition. Image smoothing is one of the pre-processing tasks which balance the effect of noise while capturing the images in specific applications. Smoothing address poor quality of captured image by reducing the noise from it, thereby enhancing accuracy of pattern classification or recognition algorithm. Performance of some frequently used smoothing techniques viz–Median filtering, Gaussian filtering, Robust filtering and Mean filtering (averaging)is analyzed in this work. Sample high quality images are contaminated with predefined levels of Gaussian noise, Speckle noise and Impulse valued noise (salt and pepper noise) manually. Performance of mentioned smoothing techniques is also checked for real time captured images through webcam. Peak Signal to Noise Ratio (PSNR) is used as quality metric to compare the versatility of one method with the other. Entire experimentation is implemented on an i3 processor machine using Matlab14a. It is found that the Median filtering method outperforms all other three methods to address the effect of noise.**

Keywords—Image smoothing; Median filtering;Robust filtering; PSNR; Real time image.

I. Introduction

Image processing has gained popularity in recent years due to its ability to provide incisive solutions to wide variety of critical applications like surveillance, security, object/person identification, healthcare, transportation management, geographical analysis and so on. Most of the real time applications suffer due to poor quality of the captured image.Artifacts are introduced during image acquisition in such applications. In case of Diabetic retinopathy analysis, retinal image of patient becomes noisy due to patients chin movement,in case of cancer analysis, MRI (Magnetic resonance imaging) images of the patient gets hampered due to thermal noise, patient movement on bed and sometimes because of the imaging system itself, similarly in case of person/object identification, the accuracy of recognition algorithm reduces significantly if the captured images are hampered with motion blur (noise).

Image smoothing is a process of enhancing the quality of noisy images by reducing noise content from them.So far, numerous approaches are introduced by researchers to address this challenging issue in signal processing domain[1].Weighted median filtering approach is found to be suitable for nose tip detection in face recognition application [2]. Theirmethod increased the performance of feature detection algorithm by implementing a weighted median filtering as a smoothing technique. Hu cheng et al. successfully used adaptive smoothing technique for intensity correction in (MRI) images [3]. MRI images are prone to Rician noise. This noise makes quantitative measurements difficult. The non-local means (NLM) filter has been proven to be effective against additive noise.NLM filter based method found to be computationally heavy but equally efficient [4]. Gu Sui Cheng et al. proposed Laplacian smoothing transform for extracting low frequency information from face images in order to get improved response of their face recognition system. Their method is found to be superior to other pre-processing methods, such as discrete cosine transform (DCT), principal component analysis (PCA) and discrete wavelet transform (DWT) [5].Moreover, in real time situations images are contaminated with motion blur, Gaussian noise, speckle noise, Salt-pepper noise and thermal noise while capturing them by image acquisition devices. Here, we have studied the efficiency of simple and computationally light image smoothing techniques. Some high quality images are forcefully contaminated with predefined levels of noise and then the proposed filtering techniques are tested for their performance. PSNR of images after contamination and smoothing is compared to identify efficient approach among implemented ones. The rest of this paper is organised as follows. Theoretical background of the proposed smoothing techniques is discussed in Section II. Section III presents the details of experimentation and results we obtained. Finally, section IV covers the concluding remarks and scope for improvement.

II. Proposed smoothing techniques

Four simple smoothing techniques viz- Median filtering, Gaussian filtering, Robust filtering and Mean filtering are implemented and tested in this work. Flow of adopted methodology is illustrated in the flowchart shown in figure 1. Detailed explanation of the steps involved in this work is as follows.

A. Aquiring/Importing test image

Test image is the image whose visual quality is to be analyzed with the help of proposed methods. Here, test image is either captured in real time through webcam or chosen from a set of Matlabs high quality built in system images. We have chosen 'eight.tif' built in image for our experimentation. Performance of proposed methods is independent of scale, type and data type of the images.

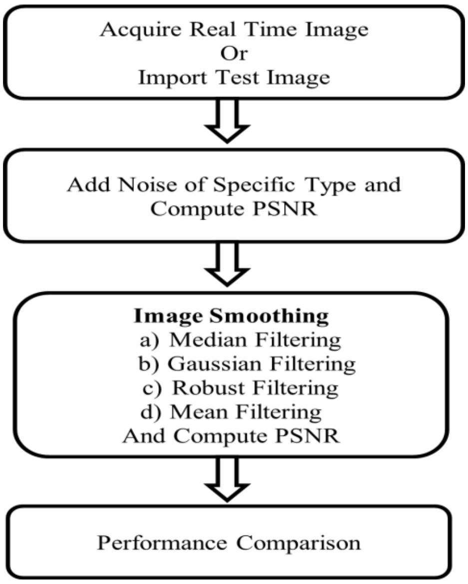


Fig. 1 Adopted methodology

B. Adding noise of specific type

Removing or minimizing noise from the digital images is very difficult without the prior knowledge of noise model. Detailed review of noise models is studied by Ajay et al. [6]. We have selected specific kinds of noise for our experimentation such as Gaussian noise, Speckle noise and Impulse valued noise. They are characterized by variance ranging from 0 to 1. One dimensional mathematical model of Gaussian noise, Speckle noise and Impulse valued noise is represented by equation 1, 2 and 3 respectively.

$$P(x) = \sqrt{\frac{1}{2\pi\sigma^2}}\, e^{-\frac{(x-\mu)^2}{2\sigma^2}} \quad (1)$$

$$P(x) = \begin{cases} P_a & for\ x = a \\ P_b & for\ x = b \\ 0 & elsewhere \end{cases} \quad (2)$$

$$P(x) = \frac{2x}{\sigma^2}\, e^{-\frac{x^2}{\sigma^2}} \quad (3)$$

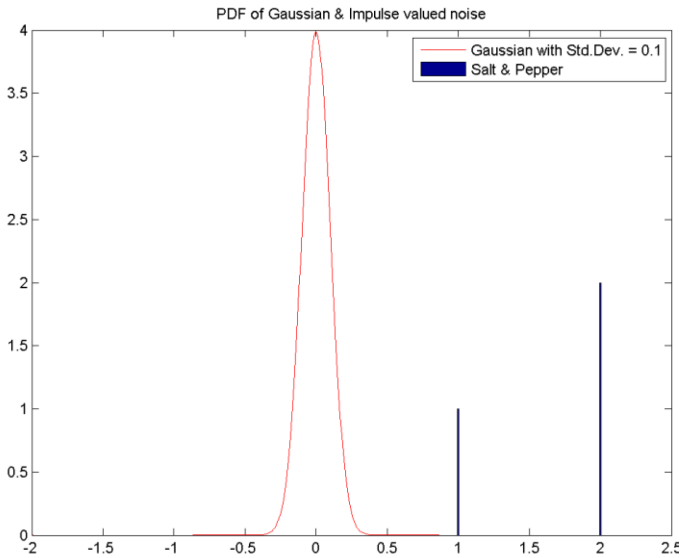
Their probability density functions (PDF) for specific value of variance are shown in figure 2. Here we add predefined amount of noise of each type in the test image.

C. Filtering techniques

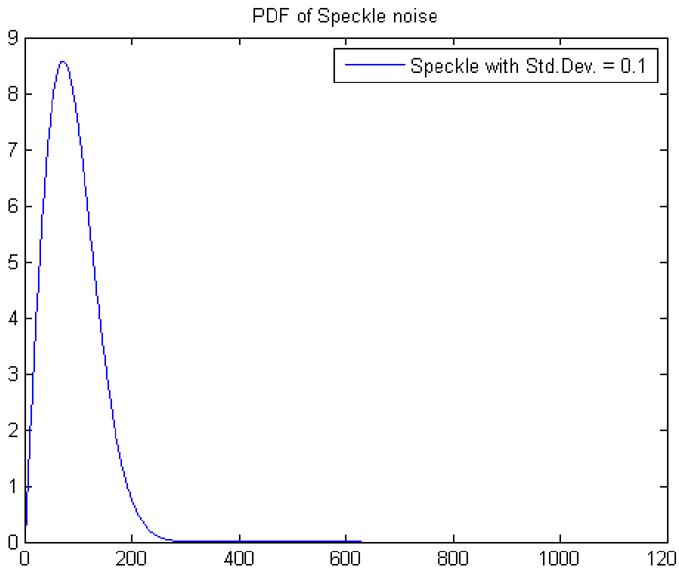
Fundamentally noise is a high frequency component present in the image. So, a Low Pass Filter (LPF) is required to reject such high frequency component. Hence we designed following special filtering approaches to enhance the visual quality of the image.Our designed smoothing filters are tested on quality hampered images (images with poor PSNR) obtained in stage *B.*

I. Median filtering

This is most simple, fast and reliable filtering technique to counterbalance effect of noise in noisy images. The Median filter replaces the central value of an M-by-N neighborhood with its median value. If the neighborhood has a center element, the block places the median value there. The kernel of designed median filter is of size3 by 3. The more the kernel size, the poorer will be the response of median filtering.



(a)



(b)

Fig. 2Probability Density functions (a) Gaussian noise and Salt – Pepper noise (b) Speckle noise

II. Gaussian filtering

It is a filter whose impulse response is a Gaussian function or an approximation to it.Because of its Gaussian impulse response it appears to be LPF, suitable to remove noise from signals. Gaussian filter is a linear filter. It is usually used to blur the image or to reduce noise from it. We have designed the Gaussian filter of size 10 and standard deviation of 0.1.

III. Average filtering

It is also known as mean filtering. It is simple, intuitive and easy to implement method of smoothing images, i.e. reducing the amount of intensity variation between one pixel and the next. Typical averaging filter processes the image block wise. We have kept the block size of mean filter to be of 3 by 3 to obtain better results.

IV. Robust filtering

Robust smoothing filter is a simple and fast nonlinear filter. It responds effectively to remove low density salt and pepper noise, because it adopts the strategy of losing the ability of smoothing to preserve edges, it can preserve more edge details than that of median filtering. In robust filtering, mean value (*M*) of the pixel intensities in a block size of 3 by 3 is compared with individual pixel intensity $I(x, y)$ of the test image. If the value of pixel intensity is observed to be less than *M*, the pixel intensity is replaced by M else the pixel intensity is restored as it is.

D. Computing PSNR

Peak signal to noise ratio in case of 2-D signals is computed using standard equation used in literature and shown in equation 4. PSNR of noisy image and all smoothed images is computed in stage *B* and *C* respectively. Acquired or imported image is considered as a reference for computation of PSNR in both the stages.

$$SNR = \frac{\sum\sum[f^*(x,y)]^2}{\sum\sum[f(x,y) - f^*(x,y)]} \quad (4)$$

$$PSNR = 10\log_{10}(SNR) \quad dB$$

III. EXPERIMENTATION AND RESULTS

Gaussian noise, Speckle noise and Salt-pepper noise is added to the test image with five different levels of specific standard deviations. The range of standard deviationof mentioned noises we chose to add in test image is [0.1 0.14 0.22 0.31 0.44]. Thus visual quality of high quality test image is hampered intentionally to check the performance of proposed smoothing techniques. Adding noise in test image significantly drops its PSNR value (in db). Tabulated result gives clear idea about performance of all four smoothing techniques for each noise case with its standard deviation mentioned above.

From Table 1 it is evident that the Median and Mean filtering works efficiently on Gaussian noise where as Median and Robust filtering methods out perform better on salt and pepper noise. It is also evident that the Robust filtering approach takes over remaining all proposed methods when the density of speckle noise is increases in test image. Average computational time taken by each of the proposed smoothing technique is 4.67 seconds. Complete experimentation is performed using Matlab2014a platform strictly on gray scale images. Built in gray scale image 'eight.tif' is used for the analysis purpose. Figure 3 and 4 depicts high quality test image and image after adding mentioned noise types respectively. Figure 5 shows the result of proposed smoothing techniques on obtained noisy image.

TABLE 1. RESULT OF COMPUTED PSNR

PSNR values in db for Gaussiannoise					
Operation	σ = 0.1	σ = 0.14	σ = 0.22	σ = 0.31	σ = 0.44
Noisy Image	43.53	37.53	29.25	23.05	17.50
Median filtering	54.82	50.26	43.23	37.53	31.66
Averaging filter	52.78	49.94	43.40	36.80	29.91
Robust filtering	50.50	46.38	40.28	35.22	30.54
Gaussianfiltering	49.21	45.63	38.85	32.62	26.27
PSNR values in db for Speckle noise					
Operation	σ = 0.1	σ = 0.14	σ = 0.22	σ = 0.31	σ = 0.44
Noisy Image	47.25	41.66	33.38	27.14	20.11
Median filtering	54.74	50.04	43.43	37.38	31.61
Averaging filter	53.85	51.74	45.97	39.29	31.22
Robust filtering	52.72	49.66	45.27	40.27	35.18
Gaussian filtering	50.64	47.93	42.08	35.68	28.09
PSNR values in db forSalt and Peppernoise					
Operation	σ = 0.1	σ = 0.14	σ = 0.22	σ = 0.31	σ = 0.44
Noisy Image	51.94	44.55	35.32	28.11	21.12
Median filtering	65.36	65.36	63.54	60.29	54.04
Averaging filter	54.80	53.00	48.74	43.31	35.78

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Robust filtering	62.77	58.95	52.07	46.21	38.92
Gaussian filtering	52.22	53.00	44.19	38.32	31.09

Fig. 3. High quality test image

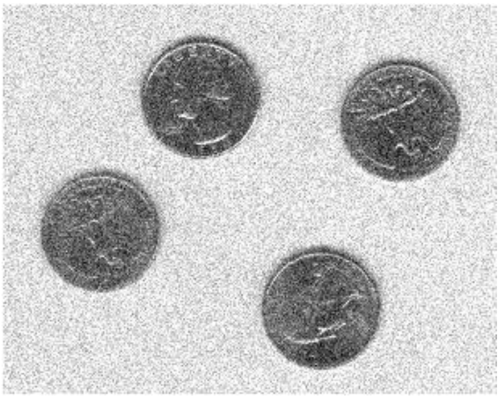

Fig. 4. Gaussian noisy image

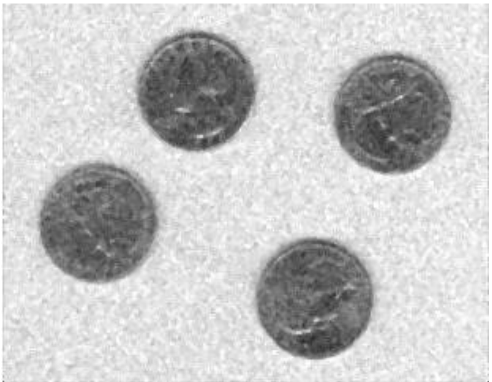

Fig. 5 (a) Median filtered image

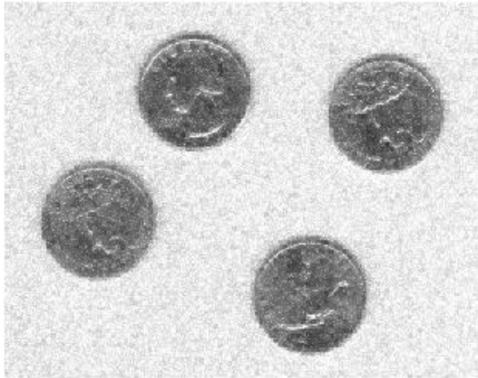

Fig. 5 (b) Robust filtered image

Similar experimentation is done on real time images by web cam captured images. Result on one such image is shown in figure 6.

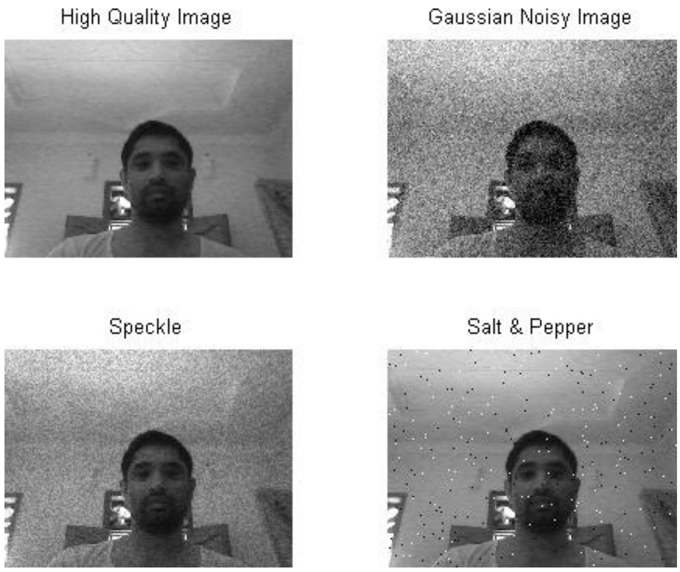

Fig. 6 (a) Real time captured image added with noise

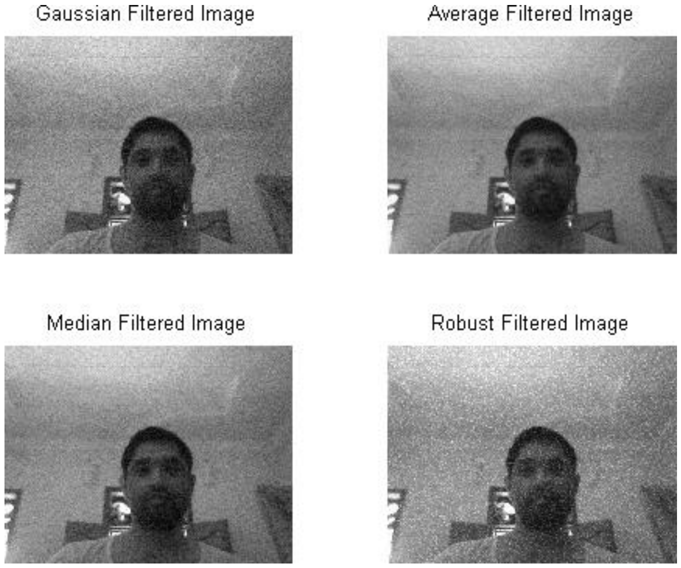

Fig. 6 (a) Gaussian noisy image after smoothing

V. CONCLUSION

In this paper simple, computationally lean and efficient image smoothing techniques are tested. Their performance is compared with each other using PSNR as a key metric. Efficient image smoothing technique improves the PSNR of the noisy image greatly. Our experimentation divulge median filtering as most superior smoothing method among all where as Robust filtering is also found to be performing well in specific situations. Similar methods can be tested for colour image smoothing. Other techniques may further be combinedwith proposed techniques to obtain even better results.

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