Automatic Noise Identification in Images using Statistical Features

[1]Dr. P. Subashini. [2]Bharathi.P. T
Dept. of Computer Science, Avinashilingam Deemed University for Women, Coimbatore, India

Abstract
Noises are unwanted information which will be normally present in an image. It should be removed in such a way that the important information present in an image is preserved. De-noising an image is very active research area in image processing. There are several algorithms for de-noise but each algorithm has its own assumptions, advantages and limitations. The method proposed in this paper uses a simple pattern classification for noise identification. The significant idea is to obtain the noise samples and to extract their statistical feature for identifying the noise type. Simple image filters are used to get the noise samples and noise identification is achieved by using few statistical features. The method is capable of accurately classifying the type of noise besides the type of images used.

Keywords
De-nosing, Homomorphic filter, Kurtosis, Skewness, statistical features.

I. Introduction

Digital images play an important role both in daily life applications such as satellite television, magnetic resonance imaging, computer tomography, geographical information systems and astronomy. One of the most interesting aspects of this information revolution is the ability to send and receive complex data that transcends ordinary written text. Noise modeling in images is greatly affected by capturing instruments, problems with the data acquisition process and interfering natural phenomena can also degrade the data of interest, transmission media, image quantization and discrete sources of radiation.

An automated technique for identification of image noise is really important because once the type of noise is identified from the given image an appropriate algorithm can then be used to de-noise it. Only a few researchers have addressed this issue till date [1 – 2]. However, the proposed algorithms are complicated because their main goal is to estimate the statistical parameters of the noise. For instance, the authors of [1 - 2] proposed a fairly complicated method based on detection of homogeneous regions, unsupervised variational classification through a multi-threshold technique and estimation of statistical parameter from the homogeneous regions.

The method in this paper uses a simple technique for identifying the type of noise present in an image which is required in many applications that call for superior de-noising performance. Thus de-noising is often a necessary and the first step to be taken before the images are analyzed to extract the useful features from an image. Since poor de-noising often results from poor noise identification, a better noise identification technique is always preferred.

The method used in this paper has been organized in the following manner, section II describes different type of noise models, section III describes proposed Noise identification method, section IV describes implementation and analysis, section V describes the result, section VI gives conclusion and finally all the references been made for completion of this work.

II. Different type of noise models

Noise is a disturbance that affects a signal and may distort the information carried by the signal. Image noise can also be originated due to the electronic noise in the sensors in the digital cameras or scanner circuitry and also the heat generated might free electrons from the image sensors itself, thus contaminating the “true” photoelectrons. Many types of noises exist today. They are mainly classified as follows [7]:

A. Additive Noise

The additive noise is primarily caused by thermal noise (fundamental noise), which comes from the reset noise of capacitors. Thermal noise is a random fluctuations present in all electronic systems. The mathematical model given for additive noise type is:

$$f(i, j) = y(i, j) + w(i, j) \qquad (1)$$

where $1 \le i \le M$, $1 \le j \le N$.

Let M and N be the size of the original image y(i, j), w(i, j) be the noisy image and f(i , j) is the noisy image.

B. Multiplicative Noise

This kind of noise is also called as the speckle noise [5 , 6 , 10]. This noise gives a magnified view of the area and there is a higher random variation observed. On the other hand, when this noise is applied to a darker region in the image, the random variation observed is not that much as compared to that observed in the brighter areas. Thus, this type of noise is signal dependent and distorts the image in a large way. The mathematical model for multiplicative noise type is:

$$f(i, j) = y(i, j) * w(i, j) \qquad (2)$$

where $1 \le i \le M$, $1 \le j \le N$

Let M and N be the size of the original image y(i, j), w(i, j) be the noisy image and f(i , j) is the noisy image.

C. Impulsive Noise

Impulsive noise is sometimes called as salt-and-pepper noise or spike noise. This kind of noise is typically seen on digital images. It represents itself as randomly occurring white and black pixels. An image containing this type of noise will have dark pixels in bright regions and bright pixels in dark regions. It can be caused by dead pixels, analog-to-digital converter errors, bit errors in transmission, etc [8 , 9].

$$f(i,j) = \begin{cases} r_{ij} & with \quad probability \quad r \\ y_j & with \quad probability \quad 1-r \end{cases} \qquad (3)$$

ISSN : 2229-4333(Print) | ISSN : 0976-8491(Online)

Let y_{ij} be the gray level of a true image y at pixel location (i, j), ω_{ij} be the gray level of the noisy image ω at pixel (i, j), r_{ij} are random numbers and r is the noise ratio.

III. Proposed Noise identification method

The basic principle consists of three main steps to identify the noise type.

Step 1 : Extract respective noise samples from the given noisy image
Step 2 : Estimate statistical features such as Kurtosis & Skewness
Step 3 : Use a simple pattern classifier to identify the type of noise.

The above steps can be summarized as follows:
Assume the original M×N image y(i, j) is contaminated by either additive or multiplicative type of noise, ω(i, j) . Thus the observed image f (i, j) can be modeled as equation (1) for additive noise, equation (2) for multiplicative noise and equation (3) for impulsive noise.
To start with it has been assumed that the type of noise is unknown, but it belongs to one of N known classes. For each type of noise, choose a simple linear or nonlinear spatial filter operator capable of removing most of the noise type from the image. Suppose Hk(i,j), where 1≤ k ≤ N, denote these filter operators. To extract some noise samples, first process the image through each filter operator to obtain:

$$g_k(i,j) = H_k(i,j)\ f(i,j),\ 1\leq k \leq N \quad (4)$$

Next, subtract each processed image, gk(i,j), 1≤ k ≤ N, from f(i,j) to extract respective noise samples, where $w_k(i,j)$, corresponding to each type of noise

$$w_k(i,j) = f(i,j) - gk(i,j),\ 1\leq k \leq \quad (5)$$

Next, estimate some simple statistical based features from $w_k(i,j)$, 1≤ k ≤ N, and then classify the noise into one of N known classes using similarity measures, S_{fk}, 1≤ k ≤ N, where S denotes the similarity features measured with respect to the kth type of noise. The 4[th] order moments Kurtosis of a random variable X is defined as

$$Kurt(X) = \frac{E\left[(X-\mu)^4\right]}{\sigma^4} \quad (6)$$

where μ and σ are the mean and standard deviation of X. The 3[rd] order moments Skewness of a random variable X is defined as

$$Skew(X) = \frac{E\left[(X-\mu)^3\right]}{\sigma^3} \quad (7)$$

where μ and σ are the mean and standard deviation of X. First, the three selected filters, Wiener filter, Homomophic filter and Median filter are applied to the noisy image f (i, j) to get three different estimates $\bar{y}_n(i,j)$ the original image y(i, j) as follows:

$$\bar{y}_{Wiener}(i,j) = f(i,j) * H_{Wiener}(i,j) \quad (8)$$

$$\bar{y}_{Homo}(i,j) = Exp\left[\log(f(i,j) * H_{Wiener}\right] \quad (9)$$

$$\bar{y}_{Median}(i,j) = f(i,j) * H_{Median}(i,j) \quad (10)$$

Where the symbol ∗ used in the above equations denotes the associated spatial filtering operations. In equation (9) logarithm and exponential operations are needed to perform Homomorphic filtering to remove the multiplicative noise.

Then, three noise estimates based on the outputs from the three filters are obtained as follows:

$$\omega_{Wiener} = f(i,j) - \bar{y}_{Wiener}(i,j) \quad (11)$$

$$\omega_{Homo} = f(i,j)\ /\ \bar{y}_{Homo}(i,j) \quad (12)$$

$$\omega_{Median} = f(i,j) - \bar{y}_{Medianr}(i,j) \quad (13)$$

The equations (11) – (13) which results in noise estimates for each filter are used to identify the noise type.

IV. Implementation and analysis

In this paper, consider three different types of commonly occurring image noises, namely, Gaussian white noise [3 , 4], Speckle noise and Salt-and-Pepper noise. Among these three types, Gaussian white noise is of additive type, Speckle noise is of multiplicative type and Salt-and-Pepper noise is impulsive type in nature. Filters used are Wiener filter for Gaussian white noise, Homomorphic filter for Speckle noise and Median filter for Salt-and-Pepper noise. The statistical features used are Kurtosis and Skewness.

Suppose ω (i, j) is Salt-and-Pepper noise, then $\bar{y}_{Median}(i,j)$ should give the best estimate of y(i, j) and therefore ω_{Median} given in equation(13) should be close to Salt-and-Pepper noise. A simple minimum distance pattern classifier based on measuring the similarity of Kurtosis and Skewness values is used to evaluate how close ω_{Wiener} is to Gaussian white noise, ω_{Median} is to salt-and-pepper noise and ω_{Homo} is to speckle noise.
To measure the similarities:

- ✓ First generate training sequences of Salt-and-Pepper noise.
- ✓ Then, filter each noise sequence through the Median filter.
- ✓ Then estimate the Kurtosis and Skewness of each filtered noise sequence and compute their average to yield the reference values of Kurtosis and Skewness for the Salt-and-Pepper noise.

if $Kurt_{Median} \leq T$

$$SF_{Gaussian} = 0.5 * \left[\frac{\min(Kurt_{Wiener}, Kurt_{Gaussian\_Wiener})}{\max(Kurt_{Wiener}, Kurt_{Gaussian\_Wiener})} + \frac{\min(Skew_{Wiener}, Skew_{Gaussian\_Wiener})}{\max(Skew_{Wiener}, Skew_{Gausian\_Wiener})} \right] \quad 14)$$

$$SF_{Speckle} = 0.5 * \left[\frac{\min(Kurt_{Homo}, Kurt_{Speckle\_Homo})}{\max(Kurt_{Homo}, Kurt_{Speckle\_Homo})} + \frac{\min(Skew_{Homo}, Skew_{Speckle\_Homo})}{\max(Skew_{Homo}, Skew_{Speckle\_Homo})} \right] \quad (15)$$

$$SF_{S\&P} = 0$$

else

$$SF_{Gaussian} = 0 \quad , \quad SF_{Speckle} = 0$$

$$SF_{S\&P} = 0.5 * \left[\frac{\min(Kurt_{Median}, Kurt_{S\&P\_Median})}{\max(Kurt_{Median}, Kurt_{S\&P\_Median})} + \frac{\min(Skew_{Median}, Skew_{S\&P\_Median})}{\max(Skew_{Median}, Skew_{S\&P\_Median})} \right] \quad (16)$$

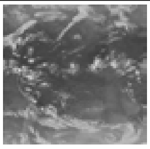
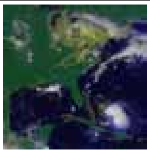
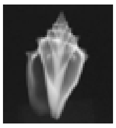
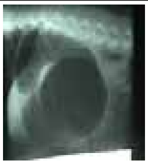
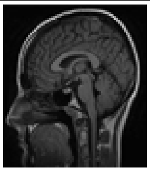
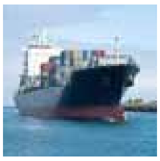
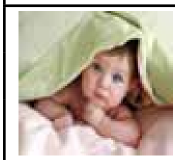
(In equation (16), $Kurt_{Median}$ and $Skew_{Median}$ denote Kurtosis and Skewness of ω_{Median} , $Kurt_{S\&P\_Median}$ and $Skew_{S\&P\_Median}$ denote the expected Kurtosis and Skewness of ω_{Median} if the original noise $\omega(i, j)$ is actually Salt-and-Pepper noise. Minimum and maximum operations are used to assure that the maximum similarity value is 1. The similarities of Kurtosis and Skewness are equally weighted to get $SF_{S\&P}$, the final measure of similarity between ω_{Median} and actual Salt-and-Pepper noise. The same procedure is carried out to obtain the expected Kurtosis and Skewness values for Speckle noise and Gaussian white noise. Finally, based on experimental data, the value of T which was the threshold was chosen to be 30 in this set of experiments.

V. Results and discussions

The results are generated by using matlab simulations. The methodology is examined with satellite images, x-ray images, MRI images and also digital images, with three different noise types. The images are filtered by using Wiener filter, Homomorphic filter and Median filter. Table 1 shows the calculated Kurtosis, Skewness, and their similarities and also the identified noise types and Fig. 1 shows the output of statistical features of Gaussian white noise, Speckle noise and Salt-and-Pepper noise. Minimum and maximum operations are used to assure that the maximum similarity value is 1.

 ISSN : 2229-4333(Print) | ISSN : 0976-8491(Online)

Table 1: Kurtosis, Skewness, and their similarities and also the identified noise types

Image Type	Noise Input	Kurt Wiener	Kurt Homo	Kurt Median	Skew Wiener	Skew Homo	Skew Median	$SF^{Gaussian}$	$SF^{Speeckle}$	$SF^{S\&P}$	Noise type
	Gaussian	3.89	42.61	5.33	1.33	5.21	1.68	**0.88**	0.63	0	**1**
	Speckle	3.80	2.74	6.23	1.24	0.41	1.82	0.68	**0.82**	0	**2**
	Salt & pepper	42.01	2.38	51.35	5.75	-0.20	6.67	0	0	**0.74**	**3**
	Gaussian	3.51	26.41	7.31	1.10	4.16	2.03	**0.86**	0.76	0	**1**
	Speckle	6.00	4.45	12.50	1.75	1.12	2.78	0.71	**0.88**	0	**2**
	Salt & pepper	47.38	4.03	69.19	5.77	0.91	7.41	0	0	**0.71**	**3**
	Gaussian	3.08	25.98	7.06	0.95	4.07	1.98	**0.74**	0.64	0	**1**
	Speckle	4.92	2.60	9.00	1.47	0.46	2.20	0.42	**0.65**	0	**2**
	Salt & pepper	33.97	17.12	64.38	4.87	-2.28	7.42	0	0	**0.67**	**3**
	Gaussian	3.64	27.46	6.18	1.21	4.22	1.78	**0.83**	0.65	0	**1**
	Speckle	6.04	3.51	10.59	1.49	0.36	2.47	0.28	**0.66**	0	**2**
	Salt & pepper	39.38	3.40	58.19	5.45	-0.14	7.04	0	0	**0.74**	**3**
	Gaussian	3.16	22.26	8.42	0.98	3.79	2.17	**0.85**	0.76	0	**1**
	Speckle	8.62	16.53	19.12	2.00	2.54	3.24	0.40	**0.45**	0	**2**
	Salt & pepper	30.33	16.07	56.30	4.18	2.31	6.49	0	0	**0.66**	**3**
	Gaussian	4.85	35.25	8.66	1.46	4.82	2.27	**0.83**	0.65	0	**1**
	Speckle	7.23	11.76	11.71	1.97	2.89	2.57	0.54	**0.64**	0	**2**
	Salt & pepper	42.35	12.53	72.52	5.44	2.98	7.84	0	0	**0.66**	**3**
	Gaussian	4.95	23.37	6.36	1.57	3.81	1.89	**0.73**	0.56	0	**1**
	Speckle	5.88	4.83	6.83	1.63	1.28	2.00	0.43	**0.61**	0	**2**
	Salt & pepper	26.13	4.79	44.57	4.32	1.25	6.13	0	0	**0.75**	**3**
	Gaussian	4.61	60.07	6.25	1.50	6.10	1.85	**0.82**	0.57	0	**1**
	Speckle	5.72	14.10	5.84	1.43	2.44	1.80	0.49	**0.66**	0	**2**
	Salt & pepper	37.97	16.02	54.13	5.44	2.80	6.96	0	0	**0.75**	**3**

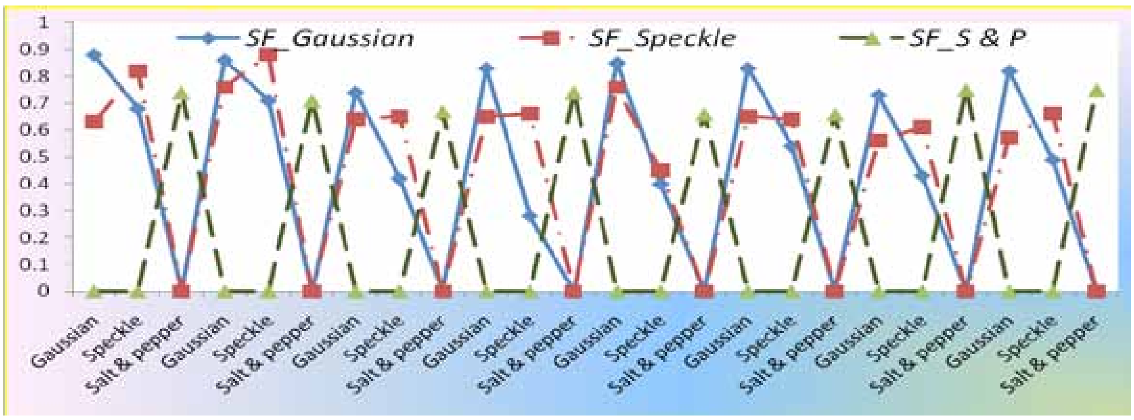


Fig.1: Statistical features of Gaussian, Speckle and Salt-and-epper noise.

From the above Table 1 and Fig. 1, one can understand that the statistical value obtained yields higher value for the respective type of noise. For example if the noise type in an image contains Gaussian noise then the statistical value obtained will be higher when compared with the statistical value of other type of noises. The noise types 1, 2 and 3 represents Gaussian noise, Speckle noise and Salt-and-Pepper noises respectively.

VI. Conclusion

Identifying the noise type is the first phase in image processing for de-noising. Once the type of noise is identified respective filters can be applied for de-noising, so it enhances the image quality and helps in future steps of image processing. This paper implements statistical feature extraction for calculating the statistical properties and a simple pattern classification scheme is applied on the features for identifying the type of noise present in an image. The method is quite general in nature and can be used with a variety of de-noising filters. The results of simulation studies seem to indicate that the method is capable of accurately identifying the type of noise.

References

[1]. M. C. Motwani, M. C. Gadiya, R. C. Motwani, F. C. Harris, Jr.," Survey of image denoising techniques", Proceedings of GSPx 2004, Santa Clara, CA, September 27-30, 2004.

[2]. Yixin Chen, Manohar Das, "An Automated Technique for Image Noise Identification Using a Simple Pattern Classification Approach", IEEE Trans, 2007.

[3]. M. A. T. Figueiredo, R. D. Nowak, "An EM algorithm for wavelet based image restoration", IEEE Transactions on Image Processing, August 2003, Vol. 12, pp. 906- 916.

[4]. M. Mihcak, I. Kozintsev, K. Ramchandran, P. Moulin, "Low complexity image denoising based on statistical modeling of wavelet coefficients", IEEE Signal Processing Letters, Vol. 6, no. 12, pp. 300-303. Dec. 1999.

[5]. Anil. K. Jain, "Fundamentals of Digital Image Processing," Prentice-Hall, 2007.

[6]. J. M. Park, W. J. Pearlman, "Speckle filtering of SAR images based on adaptive windowing, IEEE Proceedings on Vision, Image and Signal Processing, August 1999, Vol. 146, No. 4, pp. 191-197.

[7]. Mohammed Ghouse, Dr. M. Siddappa, "Adaptive Techniques based high impulsive noise detection and reduction of a digital image", Journal of Theoretical and Applied Information Technology 2005 - 2011 Jatit & Lls.

[8]. V.R.Vijay Kumar, S.Manikandan, P.T.Vanathi, P.Kanagasabapathy and D.Ebenezer, "Adaptive Window Length Recursive Weighted Median Filter for Removing Impulse Noise in Images with Details Preservation", ECTI Transactions on Electrical Eng., Electronics, and Communications Vol.6, No.1 February 2008.

[9]. D.Maheswari, Dr.V.Radha, "Noise Removal in Compound Image Using Median Filter", International Journal on Computer Science and Engineering Vol. 02, No. 04, 2010, 1359-1362.

[10]. Milindkumar V. Sarode, Prashant R. Deshmukh, "Reduction of Speckle Noise and Image Enhancement of Images Using Filtering Technique", International Journal of Advancements in Technology, Vol 2, No 1, January 2011.

Dr. P. Subashini, Associate Professor, Dept. of Computer Science, Avinashilingam Deemed University has 18 years of teaching and research experience. Her research has spanned a large number of disciplines like Image analysis, Pattern recognition, neural networks, and applications to Digital Image processing. Under her supervision she has seven research project of worth one crore from various funding agencies like DRDO, DST and UGC.

Bharathi.P. T, Research Scholar, Dept. of Computer Science, Avinashilingam Deemed University have 6 years of teaching experience. Her area of interest: Digital Image Processing and Neural Networks. She is doing her research work in Digital Image Processing using Neural Networks