Random Valued Impulse Noise Detection Schemes

Vinayak C. Sakhare[1], Sachin V. Kamble[2], Jakia A. Alase[3]

[1]*Assistant Professor, Department of Electronics, Textile & Engineering Institute, Ichalkaranji, Maharashtra, India*
[2]*Assistant Professor, Department of I.T., Textile & Engineering Institute, Ichalkaranji, Maharashtra, India*
[3]*Assistant Professor, Department of Electronics, Textile & Engineering Institute, Ichalkaranji, Maharashtra, India*

Abstract – *Digital images are often corrupted by Random Valued Impulse Noise (RVIN) causing loss of information. Hence removal of RVIN is important before subsequent image processing operations. Filters used to remove RVIN are mainly having two steps- noise detection and filtering of only corrupted pixels. So performance of the filters equally depends on noise detection scheme used. Switching Median Filter and many variants of it are using a threshold level to detect noisy pixels. Various authors have used different methods to determine either single or dual or triple threshold levels to detect noisy pixels accurately. Review of some of the methods shows that along with correct noise detection scheme, computational complexity is also important to decide filter performance.*

Key Words: RVIN, mean, median, standard deviation, threshold

1. INTRODUCTION

An image carries large amount of information and is a tool of communication between people. However images are frequently corrupted by impulse noise due to malfunctioning pixel elements in the camera sensors, faulty memory locations, timing errors in analog-to-digital conversion, and transmission errors [1]. This causes loss of information. Hence denoising is an important step before subsequent operations such as edge detection, image segmentation and object recognition etc. Impulse noise is of two types: salt and pepper noise and Random Valued Impulse Noise (RVIN). In salt and pepper noise, noisy pixel takes only extreme gray level value. For 8 bit image, these extreme gray levels are 0 and 255 due to which pixel appears as black and white dot. Hence name given is salt and pepper noise. In RVIN, noisy pixels are taking any random value from 0 to 255.

The objective of digital filter is to identify corrupted pixels and replace them with a value which will be equal to or close to the true value. Filters compute these values using some predefined relationship. Standard median filter (MF) is a simple nonlinear and reliable filter to remove the impulse noise without damaging edges [2]. The main disadvantage of median filter is, it applies median filtering scheme to each pixel without considering whether pixel is corrupted or not. It shows that noise detection is important because it greatly affects performance of filter. Since due to RVIN, corrupted pixel is tanking any random value, detecting RVIN is very difficult task.

Adaptive median filter (AMF) uses noise detection scheme. AMF works in rectangular window area. It replaces only noisy pixels by median of the window. Ranked order based adaptive median filter (RAMF) detects noisy pixel by using minimum, maximum & median of intensity values from the neighbourhood window and maximum filtering window size [3].The performance of RAMF is better than that of median filters at lower noise density levels. However, at higher noise densities, the edges are smeared significantly because large numbers of pixels are replaced by median values which are less correlated with actual pixel value [4].

In switching median (SWM) filter [5], the decision of corrupted image pixel is based on a pre-defined threshold value. SWM filter is a two steps procedure. First step is a noise detection step, wherein a pixel is deemed as noisy if the absolute difference between the median value in its neighbourhood and the value of the pixel itself is greater than a given threshold. Second step is filtering step in which classical median filter is applied for only noisy pixels.

One main limitation of this method is the threshold value is defined a priori or chosen after many data dependent tests. Though the literature shows that an optimal threshold in the sense of the mean square error can be obtained, threshold suitable for one particular image can not necessarily be adapted to another one [6]. In addition, without considering the local characteristic, such as the local mean and the local standard deviation, using same threshold for noise detection, is not a good idea [7]. To overcome drawback of SMF, various researchers have proposed numerous schemes for RVIN detection in which threshold level is not defined a priori. Since RVIN detection is a stringent task, review of such few methods is presented in this paper.

2. Review of RVIN detection schemes

To overcome limitation of SWF, S. Akkoul et al. have proposed Adaptive SMF (ASMF) [6] in which threshold is not a priori choice. It is computed locally from image pixels. In this filter, for weighted mean value and weighted standard deviation are estimated from neighbourhood window of current pixel. The weights are the inverse of the difference between the weighted mean value of pixels in a given window and the considered pixel. In each window, the weighted mean is estimated first iteratively. Then the weighted standard deviation is calculated and the local Threshold is determined using weighted standard deviation. Then if absolute difference between the current pixel and weighted mean is greater than local threshold then current pixel is deemed as noisy and replaced by median of neighbourhood window. Simulation results shows that value of weighted standard deviation varies as per image regions. This adaptability is an important point to preserve image details.

However, at high noise densities, some noise values may be far from their neighbour's values. In such case, the weighted standard deviation could be large so that the absolute difference between the weighted mean value and the value of the current pixel itself is less than the local threshold. Thereby noisy pixel would be falsely deemed as uncorrupted [7]. Thus, it needs to find a way to overcome this drawback.

To overcome drawback of ASMF Adaptive Non-local Switching Median (ANSM) detector is proposed by X. Lan et al. in [7]. Noise detection scheme used is as follows. The processing pixel is in nine neighbouring sub-windows of size 3 * 3. For each of these sub-windows weighted mean and weighted standard deviation, absolute difference between weighted mean value & current pixel and local threshold is estimated as in ASMF. The sum of these absolute differences of sub-windows in which absolute difference is greater than local threshold is computed. If this sum is greater than a threshold n which is chosen through extensive experiments then current pixel is noisy.

In filters which are using single threshold value/ level to detect noisy pixel, pixels having value smaller than (or greater than) the given threshold level are considered as noisy. In this system, the range of pixel values used for identifying the noisy pixels will be large. This may increase the possibility of incorrect detection. To overcome this limitation, V. Gupta et al. have proposed adaptive dual threshold median filter [8]. In this method, a filtering window W of size r * r is formed for each pixel.

Generally, in images, gradual changes in adjacent pixel values are more common as compared to the abrupt changes. Noise corruption at any pixel would change its gray level with respect to its surrounding pixels. Average values of a set of samples (data values) always lie in close proximity to the values under consideration. Hence any sudden change in pixel value can be easily identified by analyzing it with respect to average values. Based on this fact, averages of rows and columns of filtering window are calculated. Minimum and maximum value of these averages are used as minimum threshold (Th_{min}) and maximum threshold (Th_{max}) respectively. If value of pixel under processing is lying in between Th_{min} and Th_{max} then the pixel is deemed as noise free otherwise noisy. Noisy pixel is replaced by median of filtering window.

While detecting high density RVIN, it may happen that, some of the noise-free pixels are detected as noisy pixels and vice versa. Hence the filtering stage not only fails to correct all the noisy pixels but also alters some noise-free pixels which were detected as noisy pixels. In order to overcome the miss detection, N. Singh et al. have proposed triple threshold statistical detection filter [9]. Statistical tools such as standard deviation, mean, and quartile are used to determine thresholds.

To determine first threshold, 5 * 5 window A centering on current pixel is formed. Then mean (μ_A) and standard deviation (σ_A) of all pixels of A except Central Pixel (CP) is calculated. Absolute differences of all pixels of A with mean μ_A except CP are calculated. Then mean (μ_p) and standard deviation (σ_p) of all these absolute differences is calculated. Sum of this μp and σ_p defines first threshold T_1. Then absolute difference of CP with rest all pixels of A is calculated. Mean of these values μq is used as Noise Signature (NS). If NS is greater than equal to T_1, CP is noisy pixel otherwise algorithm moves to determine second level of thresholds as below

$$T_{2min} = \mu_A - K * \sigma_A$$

$$T_{2max} = \mu_A + K * \sigma_A$$

Here K is multiplication factor and its optimum value is derived empirically for various random sets of pixels through simulations. The reason behind taking mean μ_A and standard deviation σ_A for setting these thresholds is that most of the noise-free pixels would fall within the above thresholds since they smoothen out the pixel values and generally tend towards a value resembling a noise-free pixel. If CP is less than or equal to T_{2min} or CP is greater than or equal to T_{2max}, then CP is noisy else algorithm moves to estimate third level of thresholds T_{3min} and T_{3max}.

T_{3min} is first quartile of set of all pixels of A except CP and T_{3max} is third quartile of set of all pixels of A except CP. If CP is less than or equal to T_{3min} or CP is greater than or equal to T_{3max}, then CP is noisy.

This algorithm uses three levels of thresholds to yield higher level of accuracy in detection and it also provides low computational complexity. Extensive simulation results shows that this algorithm outperforms various other filters both quantitatively and qualitatively even at very high noise intensity levels.

Region based noise detection approach [10] is proposed by S. Bannerji et al. In this method, 5 * 5 size neighbourhood window centered on current pixel is formed. The elements of are sorted in ascending order to form a set S. four subsets S1, S2, S3 and S4 are formed from set S as follows. Elements of set S having values 0 t 60, 61 to 120, 121 to 180 and 181 to 255 are placed in subsets S1, S2, S3 and S4 respectively. Then number of elements each subset is having are counted. For the subset having maximum number of elements, mean and from that standard deviation is computed. If absolute difference between current pixel and mean is greater than standard deviation, then current pixel is deemed as noisy pixel else noise free pixel. In this algorithm, it is considered that the noise free pixel will increase the number of elements in corresponding subset.

3. CONCLUSION

To avoid loss of information, filtering of RVIN is important. Along with filtering scheme, performance of filters equally depends on noise detection technique used. Since RVIN is taking any random value, detecting noisy pixel is very stringent task. Various RVIN detection schemes incorporating non priori threshold determination are reviewed. These methods are using single, dual or triple thresholds to detect impulse noise very accurately to minimize incorrect detection. Performance of these methods is to be analyzed not only in terms of correct detection but also computational complexity

REFERENCES

[1] R. C. Gonzalez and R. E. Woods, Digital Image Processing. Englewood Cliffs, NJ: Prentice-Hall, 2002.

[2] W. K. Pratt, "Median filtering," Tech. Rep., Image Proc. Inst., Univ. Southern California, Los Angeles, Sep. 1975.

[3] H. Hwang and R. A. Haddad, "Adaptive median filter: New algorithms and results," IEEE Trans. Image Process., vol. 4, no. 4, pp. 499–502, Apr. 1995.

[4] K. S. Srinivasan and D. Ebenezer, "A new fast and efficient decision based algorithm for removal of high density impulse noise," IEEE Signal Process. Lett., vol. 14, no. 3, pp. 189–192, Mar. 2007.

[5] T. Sun and Y. Neuvo, "Detail preserving median based filters in image processing," Pattern Recognit. Lett., vol. 15, pp. 341–347, 1994

[6] S. Akkoul, R. Lédée, R. Leconge, and R. Harba, "A New Adaptive Switching Median Filter", IEEE Signal Processing Letters, vol. 5(17), pp. 587- 590, 2010

[7] X. Lan, and Z. Zuo, "Random-valued impulse noise removal by the adaptive switching median detectors and detail-preserving regularization", Optik – Int. J. Light Electron. Opt. 125 (3) (2014) 1101–1105

[8] V. Gupta, V. Chaurasia, and M. Shandilya, "Random-valued impulse noise removal using adaptive dual threshold median filter", Journal of Visual Communication and Image Representation, Vol. 26, pp. 296- 304, Jan 2015

[9] N. Singh, and U. Oorkavalan, "Triple Threshold Statistical Detection filter for removing high density random-valued impulse noise in images", EURASIP Journal on Image and Video Processing, 2018(1)

[10] S. Bannerji, A. Bandyopadhyay, A. Mukherjee, A. Das, and R. Bag, "Random Valued Impulse Noise Removal Using Region Based Detection Approach", Engineering, Technology & Applied Science Research, Vol. 7, No. 6, 2017, 2288-2292

BIOGRAPHIES

Vinayak C. Sakhare has completed his M. E. Electronics

Engineering degree in 2014 from Textile & Engineering Institute. His areas of interest are Image Processing, Embedded Systems.

Sachin V. Kamble has pursued his M. Tech. Computer Science and Engineering degree in 2014 from Rajarambapu Institute of Technology in 2014. His research area is scheduling and optimization algorithm, parallel computing.

Mrs. Jakia A. Alase has completed her M. E. Electronics and Telecommunication degree from Kolhapur Institute of Technology.