An Adaptive Edge Detection Algorithm for Images Corrupted with Impulse Noise

Krishna Kant Singh
Earthquake Engineering,
IIT Roorkee, Roorkee ,India

Akansha Mehrotra
Earthquake Engineering
IIT Roorkee, Roorkee ,India

Kirat Pal
Earthquake Engineering
IIT Roorkee,Roorkee ,India

M. J. Nigam
E & C Engineering
IIT Roorkee,Roorkee ,India

ABSTRACT
Edge detection is one of the most important tasks in the field of image processing. Detection of edges from noisy images is of greater importance as most images obtained are corrupted by impulse noise due to communication and transmission errors. In the proposed work a novel adaptive algorithm for finding edges of noisy images is proposed. One of the major problem with noisy images is that the noise pixels are also detected as edges, so in the proposed algorithm a threshold is used to distinguish between edge pixels and noise pixels. The value of threshold is inversely proportional to the level of details whose edges are detected and makes the algorithm adaptive. A sliding window is taken and the difference of the center pixel with all the pixels of the window whose value is not equal to zero or one is taken, But if the center pixel itself is zero or one then the difference from a noise free median is calculated. The average of the differences is checked against a threshold value. If the average value is above the threshold then it is a edge point otherwise it is noise based on this a binary image showing the edges is obtained.

Keywords
impulse noise ,edge detection, adaptive.

1. INTRODUCTION
Edge detection is an important work for object recognition and is also an essential pre-processing step in image segmentation [1],[20]. Because edges represent important contour features in the corresponding image. Edges in images occur where change in grey level values is abrupt, i.e, places where some physical properties , such as illumination , geometry and reflectance of objects. The key issue of edge detection is to filter more noises while obtaining more edge details [2].The traditional edge detection methods based on first-order gradient or second-order differentiation such as Sobel, Canny and Log are hard to efficiently extract the complex edge [3]. These edge detection methods are built for extracting edges of noise free images. In case of noisy images these algorithms
perform poorly. Thus, the edge extraction from noisy images is gaining impetus. A edge detection algorithms that extract edges of noisy images is proposed in [4] which uses a separate wavelet based noise reduction block.

Noise is introduced into images during acquisition, signal amplification and transmission [5]. An important problem of image processing is to effectively remove noise from an image while keeping its features. Impulse noise is characterized by replacing a portion of an image pixels with noise values, leaving the remainder unchanged [6],[18],[19]. Such noise is introduced due to acquisition or transmission errors [7], [6], [8]. Nonlinear filters have been developed for removing impulse noise such as the traditional median filter [6]. Extensions of the median filter [9-14] are proposed to meet various criteria, e.g., robustness, preservation of edge, or preservation of details. But most of these suffer from the problem of being complex and also at high noise densities they do not give good results. In this paper a novel adaptive edge detection algorithm is proposed , the algorithm not only removes the noise but also finds edges efficiently. A threshold value is used to distinguish between edges and noise points. The algorithm finds the average of the differences of the pixels (whose value lies in between 0 and 1) of the window from the center pixel and if the center pixel is 0 or 1 then the difference is taken from a noise free median which is calculated iteratively by increasing the window .This average value is compared with a threshold value and if it is greater than the threshold then the center pixel is set to 1 otherwise 0, this way a binary image showing the edges of the image is formed.

2. NOISE MODEL
Impulse noise is one common noise type in communications [15,16,17]. It is also known as salt and pepper noise. In this type of noise the noise has either maximum (I_{max}) or minimum value (I_{min}) of the image intensity range. An image X corrupted with impulse noise is formulated as

$$x_{i,j} = \begin{cases} n_{i,j} \text{ , with probability } p, \\ s_{i,j} \text{ , with probability } 1-p \end{cases} \quad \dots (1)$$

where $n_{i,j} \in [I_{min}, I_{max}]$ is the noisy impulse at the location (i,j) , p represents the probability of noisy pixel , $n_{i,j}$, $s_{i,j}$ is the noise free pixel with probability 1-p. Impulse noise appears as salt and pepper granules randomly distributed over the image.

3. PROPOSED WORK
This paper proposes an efficient and novel edge detection algorithm for images that are corrupted with impulse noise. Edges correspond to high frequency regions of an image, but due to the property of impulse noise that it is the minimum or maximum value poses a challenge to differentiate noisy and edge pixels from each other. To overcome this problem and find the edges of an image the proposed algorithm works as follows. For a sliding window W_M of size M × M, where M = 2L + 1 centered at x_{ij} , the algorithm first finds the similarity of the center pixel with its ((2L+1) * (2L+1) – 1) neighbors , that is if L = 1,i.e.,for a 3×3 window there will be 8 neighbors.

In this paper a 3×3 window is chosen. But when the similarity is calculated it is to be ensured that the center pixel itself is not noise and also only those neighbors are to be considered that are noise free. For an image with grey levels in the range (0,1) a pixel is considered is impulse noise if it has the value either 0 or 1.Similarly for an image with grey level in the range (0,255) impulse noise has the value either 0 or 255.To resolve this problem two cases arise based on which the similarity of the window denoted by W_{av} is calculated, as follows

CASE I: If $x_{ij} \neq 0$ and $x_{ij} \neq 1$, this implies that the center pixel is noise free and the average value of the window is calculated by taking only those neighbors that do not have the value 0 or 1 as the neighbors N_r might also be noisy and they are not to be considered.

$$W_{av} = \frac{1}{n}\sum_{r=0}^{n} |x_{ij} - N_r| \, where \; 0 < N_r < 1 \quad \ldots.(2)$$

In equation (2), n is the number of neighbors N_r whose value lies in the range zero and one.

CASE II: If $x_{ij} = 0$ or $x_{ij} = 1$, this implies that the center pixel is noisy hence it cannot be used to calculate the window average. So the average is calculated using the median of the window, but again there is a possibility that this median comes out to be noise. Therefore, the median is calculated by increasing the window size by 2 each time until a noise free median (M_{nf}) is obtained. This noise free median is now used to calculate the window average similar to equation (1), as follows

$$W_{av} = \frac{1}{n}\sum_{r=0}^{n} |M_{nf} - N_r| \, where \; 0 < N_r < 1 \quad \ldots(3)$$

In equation (3), n is the number of neighbors N_r whose value lies in the range zero and one.

The window average calculated above is used to detect edges by checking it against a threshold value. If the average value is above the threshold (δ) this implies that the pixel belongs to edge otherwise it is a non edge point. So, finally the resultant image is obtained as

$$y_{ij} = \begin{cases} 1 & if \; W_{av} > \delta \\ 0 & otherwise \end{cases} \quad \ldots(4)$$

In equation (4), δ is the adaptive threshold, with the value of threshold the level of edges can be controlled. The value of threshold is inversely proportional to the level of details that will be detected. The image comprised of the pixels y_{ij} shows the edges of the input image. The proposed algorithm is shown below.

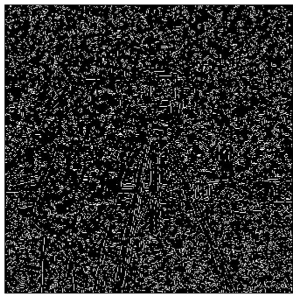
1. Input noisy image.
2. Take a sliding window W_M centered at x_{ij}
3. If $x_{ij} \neq 0 \; or \; x_{ij} \neq 1$ calculate
   $W_{av} = \frac{1}{n}\sum_{r=0}^{n} |x_{ij} - N_r| \;\; where \; 0 < N_r < 1$
4. If $x_{ij} = 0 \; or \; x_{ij} = 1$ calculate
   $W_{av} = \frac{1}{n}\sum_{r=0}^{n} |M_{nf} - N_r| \;\; where \; 0 < N_r < 1$
5. Select a threshold δ.
6. If $W_{av} > \delta$, then the output pixel $y_{ij} = 1$.
7. If $W_{av} <= \delta$, then the output pixel $y_{ij} = 0$.

4. EXPERIMENTAL RESULTS

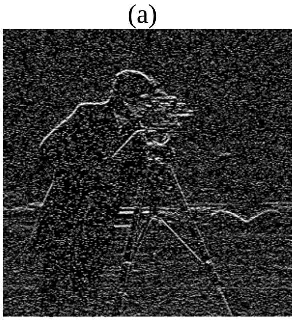
The proposed algorithm was compared with several existing edge detectors to evaluate its performance .The images have been contaminated with salt pepper noise. The results were compared on the basis of the efficiency with which the true edges are detected. Standard Cameraman grey image was taken as the test image as shown in figure1.The Proposed algorithm (PA) with the value of δ =0.03 was compared with Sobel operator (SO) and Canny edge detector (CD). Noise of different densities was added ranging from 10% to 50%. It can be seen in figure 2(b) and (c) that with 5% noise sobel operator and canny edge detector detects noise also as edges while it can be seen that the proposed algorithm finds accurate edges as seen in figure 2(c).With the noise percentage increases to 30% and 50% with Sobel and canny edge detector the edges cannot be identified at all while the proposed algorithm works well even with such high noise. It can be seen that with the proposed algorithm all the edges are detected like the fingers of the cameraman and the building behind is also detected which remains undetected with the other filters.

Fig 1:Test image cameraman

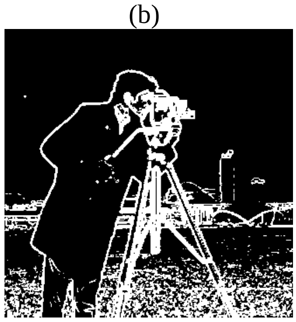
(a)



(b)

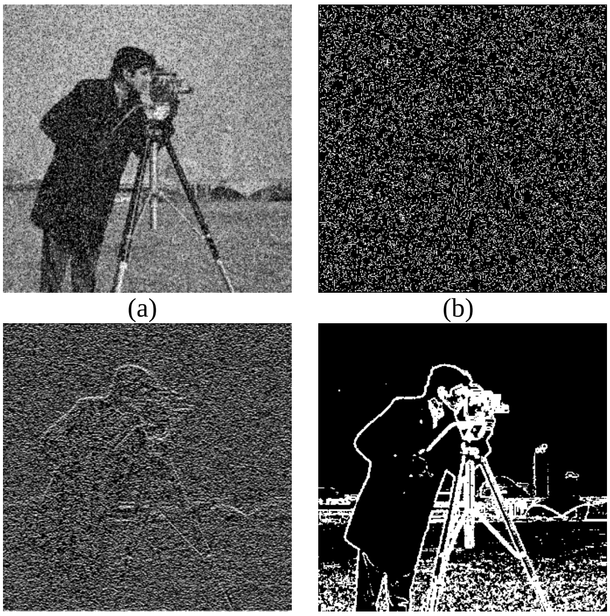


(c)



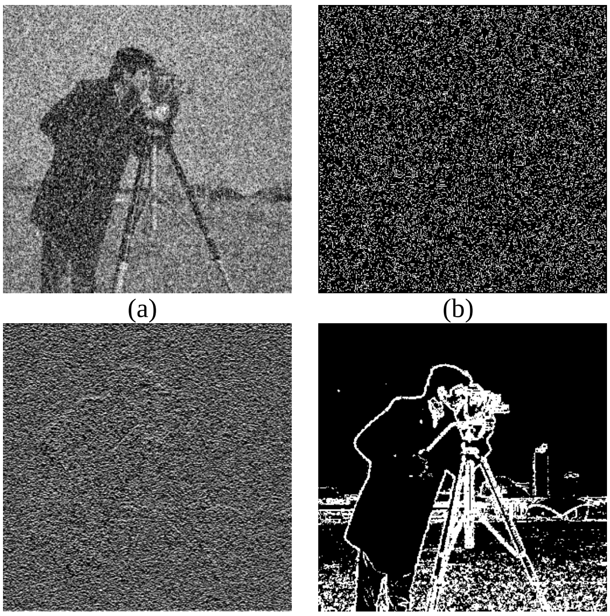
(d)

Fig 2: Edge detection using different filters (a) image corrupted with 10% salt pepper noise (b) CD (c) SO (d) PA



(a) (b) (c) (d)

Fig 3 Edge detection using different filters (a) image corrupted with 30% salt pepper noise (b) CD (c) SO (d) PA



(a) (b) (c) (d)

Fig 4 : Edge detection using different filters (a) image corrupted with 50% salt pepper noise (b) CD (c) SO (d) PA

5. CONCLUSION

An Adaptive Edge Detection Algorithm for Images Corrupted with Impulse Noise is proposed in this paper. The algorithm uses a threshold value to detect the edges of an image. The proposed algorithm finds the average of the differences of all those pixels whose value lies between zero and one with the center pixel and if the center pixel itself is zero or one then the difference from the adaptive median is calculated. The average is compared with the threshold to find the edges. The results also show that the proposed algorithm works better than the other algorithms.

6. REFERENCES

[1] M.I. Rajab, M.S. Woolfson, and S.P. Morgan, "Application of region-based segmentation and neural network edge detection to skin lesions," Computerized Medical Imaging and Graphics, vol. 28, no. 1-2,pp. 61–68, January 2004.

[2] Z. Hou and T.S. Koh. "Robust Edge Detection". Pattern Recognition,Vol. 36, pp. 2083–2091, 2003.

[3] Chen juan, Chen qian-hui, Shi lu-huan. Edge Detection Technology in Image Tracking, Chinese Journal of Optics and Applied Optics. Vol.2. No.1, pp.46-53. February 2009.

[4] Feng-ying Cui , Li-jun Zou and Bei Song , "Edge Feature Extraction Based on digital Image processing techniques,"Proc. IEEE Int'l conference Automation and logistics , Qingdao,China September 2008

[5] R. Garnett, T. Huegerich, C. Chui, and W. He, "A universal noise removal algorithm with an impulse detector," *IEEE Trans. Image Process.*, vol. 14, no. 11, pp. 1747–1754, Nov. 2005.

[6] I. Pitas and A. N. Venetsanopoulos, *Nonlinear Digital Filters: Principles and Applications*. Norwell, MA: Kluwer, 1990.

[7] W. K. Pratt, *Digital Image Processing*. New York: Wiley, 1978.

[8] I. Pitas and A. N. Venetsanopoulos, "Order statistics in digital image processing," *Proc. IEEE*, vol. 80, no. 12, pp. 1893–1921, Dec. 1992.

[9] H. Lin and A. N. Willson Jr., "Median filters with adaptive length," *IEEE Trans. Circuits Syst.*, vol. 35, no. 6, pp. 675–690, Jun. 1988.

[10] G. Pok, J. C. Liu, and A. S. Nair, "Selective removal of impulse noise based on homogeneity level information," *IEEE Trans. Image Process.*,vol. 12, no. 1, pp. 85–91, Jan. 2003.

[11]P. E. Ng and K. K. Ma, "A switching median filter with boundary discriminative noise detection for extremely corrupted images," *IEEE Trans. Image Process.*, vol. 15, no. 6, pp. 1506–1516, Jun. 2006.

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

[13] V. Crnojevic, "Impulse noise filter with adaptive MAD-based threshold," in *Proc. Int. Conf. Image Processing*, Mar. 2005, pp.337–340.

[14] N. Alajlan, M. Kamel, and E. Jernigan, "Detail preserving impulsive noise removal," *Signal Process.: Image Commun.*, vol. 19, pp. 993–1003, 2004.

[15] L. Ilzzo and L. Paura, "Error probability for fading CPSK signals in gaussian and impulsive atmospheric noise environments,"*IEEE Transactions on Aerospace*

and ElectronicSystems, vol. 17, no. 5, pp. 719–722, Sep. 1981.

[16] G. A. Tsihrintzis and C. L. Nikias, “Performance of optimum and suboptimum receivers in the presence of impulsivenoise modeled as an alpha-stable process,” *IEEE Transactions on Communications*, vol. 43, no. 234, pp.904–914, Feb./Mar./Apr. 1995

[17] L. F. Lind and N. A. Mufti, “Efficient method for modeling impulse noise in a communication system,” *Electronics Letters*, vol. 32, no. 16, pp. 1440–1441, Aug. 1996.

[18] Krishna Kant Singh, Akansha Mehrotra , Kirat Pal, M.J.Nigam, “A N8(P) Detail Preserving Adaptive Filter For Impulse Noise Removal” ,*Proceedings IEEE, 2011 International Conference on Image Information Processing (ICIIP 2011)***.**

[19.] Krishna Kant Singh, Akansha Mehrotra, M.J.Nigam, Kirat Pal, “A Novel Edge Preserving Filter For Impulse Noise Removal” , *Proceedings IEEE, IMPACT 2011***.**

[20] A. Mehrotra, K. K. Singh , M.J. Nigam and Kirat Pal, "A Novel Algorithm for Impulse Noise Removal and Edge Detection," *International Journal of Computer Applications, vol*. 38, No. 7, pp. 30-34, 2012.