Improved Median Filter using ROAD for Removal of Impulse Noise

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ABSTRACT
This paper represents a new algorithm which uses a trimmed global mean filter with ROAD to remove random impulse noise. A two step algorithm is implemented in which the first step ensure detection of corrupted pixels in the degraded image and the second step replaces the degraded image with either the median of uncorrupted pixels in the selected window and if the selected window contains noisy pixels only than trimmed global mean filter is used. To avoid computational delay and to ensure a light algorithm, the selected window is fixed [3x3] in both the detection and the filtering stage. This algorithm outperforms many filters in restoring image corrupted by random value impulse noise.

Keywords
ROAD, ROLD, Impulse Noise, Denoise

1. INTRODUCTION
Digital images are often corrupted due to transmission errors, malfunctioning pixel elements in the camera sensors, faulty memory locations, and timing errors in analog-to-digital conversion [1].When it has been discussed on noise it can be getting introduced in the image, either at the time of image generation (e.g. when we use camera and photographic films to capture an image) or at the time of image transmission. During Image acquisition, the image is converted into an electrical signal which is sampled. Sampling the Image adds to the noise in the image as the information becomes discrete. The quality of sensor also defines the quality of image. Hence image gets corrupted due to interference in transmission channel. Some transmission errors occur due to lightening or other atmospheric disturbance. Images get corrupted due to the random signal present in the environment which gets added and hence corrupts the image. One of such random noise is the Impulse Noise also Known as Salt and Pepper Noise. Digital images are often corrupted by impulse noise due to transmission errors, malfunctioning pixel elements in the camera sensors, faulty memory locations and timing errors in analog-to-digital conversion [1]. The corrupted pixel due to Impulse noise can take any grey value between [0,255] hence there is no correlation with the neighbouring pixels. This results in bright and/or dark spots in the image. These corrupted pixels are to be changed using filters in the dynamic range [0,255] ensuring not to alter the pixel value of the uncorrupted pixels [2].Some other artifacts common in old films and video sequences are streaks, blotches, scratches and stripes [3].With due time, the magnetic film material of old movies accumulates dust resulting in random scratches and blotches. To convert them into digital information results in further degraded image.

There are basically two types of distortion namely scratches and blotches. Scratches are nothing but a thin line of pixel of arbitrary shape with nearly equal gray level value. They are caused by foreign elements like dust in the camera or the projector. Blotches are blocks or small coherent area with similar gray level value. Such random pixels in the image are a type of impulse noise which can be characterized by two properties. First, discontinuity of noise in the image sequence because of distortion. Second, distortion with same or almost same gray level value in the coherent area [4].Stripes and streaks are some other artifacts that appear in digital images. A model of line interaction visible as a narrow light and dark vertical lines in an image are Known as the stripes also known as line scratches. These are generally visible in old motion pictures [5]. The images which gets contaminated by the noise, is called degraded images and by using different filters, the images can be restored. Hence de-noising is defined as a process in which the image corrupted by noise is processed by the using various detection and/or filtration techniques to achieve a image with high PSNR. Noise removal techniques are used in various applications including edge detection, image segmentation, object recognition etc. The ultimate aim of using filters is to ensure that the details of the image should be preserved in the process of noise removal.

2. LITERATURE REVIEW
Noise is an unwanted signal generally added to the original digital image due to various sources. Various noise reduction techniques are introduced depending on the type of noise. Broadly, there are two methods namely linear techniques and non-linear techniques.

In case of linear technique, the algorithm is applied evenly throughout the image irrespective of a corrupted or non-corrupted pixel. In this method, the algorithm has no information about the distinction between the corrupted and non-corrupted pixels. The main disadvantage of this method is that the original pixels also get modified. Hence to overcome this method which could work on the noisy pixels only, non-linear techniques were developed. Non-linear technique works in two steps. In first step, the corrupted pixels from the degraded images are detected. In second step, noise reduction algorithm is implemented for the detected corrupted pixels are of the degraded image. The second stage includes the implementation of various filters depending on the types of noise which works well at low noise density but for high noise density the performance of these techniques is poor. Wide ranges of filters were proposed to improve the performance of the filtering. These are : Switching Median filter (SM) [6], Multi State Median Filter (MSM) [7], CWMF (Centre Weighted Median Filter) [8], Adaptive Centre weighted Median Filter (ACWM) [9], Signal Dependent Rank Order

Mean (SD-ROM) [10], AMF (Adaptive Median Filter) [11], PSM (Progressive Switching Median Filter) [12], TSM (Tri-State Median Filter) [13], DBA (Decision Based Algorithm) [14] and SMF (Standard Median Filter) [15].

SMF is reliable to impulse noise preserving edge details. The only disadvantage is that it is effective only for low noise density. For example details of the image are not preserved when the noise density is greater than 50%. To overcome this drawback, AMF was proposed. It removes the problem when the window size is increased but results in blurring of the image. There are many SMF filters proposed based on predefined threshold value to detect and correct the corrupted pixels. Since local features are not considered into account, hence the edges and details are not recovered satisfactory. Hence to overcome the problem of removal of high density noise image, Decision Based Filter was proposed. In this case the corrupted pixels are replaced by the local median or by the neighbouring pixel but it results in streaking effect at high noise density. To overcome this problem, a two stage cascade approach [16] is proposed. The first step detects the corrupted or uncorrupted pixel. The second step includes replacement of unsymmetrical trimmed mid-point; this may damage the fine details of the image. The problem of streaking in DBA is also removed by Modified DBA [17].The corrupted pixels of the degraded image are replaced by the median of the uncorrupted pixels in the selected window. MDBF doesn't preserve edge details of the image with high noise density (up to 80%). The solution to the streaking and edge preservation problem in above filter is Modified Decision Based Unsymmetrical Trimmed Median Filter (MDBUTMF) [18].

In this, the corrupted pixels of the degraded image are replaced by mean of the selected window or by the trimmed median output. At very high noise density the edges of the image are smoothened by the filter. To overcome this problem Trimmed Global Mean Filter (TGM) [19] is proposed, in which if the selected window contains both corrupted and uncorrupted pixel the corrupted pixels are replaced by the median of the uncorrupted pixel in the selected window and if the window contains the entire pixel as corrupted the processing pixel is replaced by trimmed global mean.

Various edge preserving regularization methods has been proposed to remove impulse noise ensuring non-smoothing effect [20]. A two stage method was proposed [21] and [22] to remove impulse noise ensuring detail preservation. Adaptive median filter [23] and ACWMF [9] is used to identify corrupted pixels and edge preserving technique is to restore the corrupted pixel. It is reliable at high noise density but limited by the detector accuracy in first phase. ROAD (Rank Ordered Absolute Difference) a new statistic method is used to identify the corrupted pixels in image. This algorithm is used to remove impulse and Gaussian noise when incorporated with bilateral filter. Hence the resultant filter is known as trilateral filter [24]. The value of the ROAD method is a measure of how closely the pixel is related to its four neighbours. It has a disadvantage that it produces blurring problem at high noise density. To ensure accurate noise detection a statistic called ROLD (Rank Ordered Logarithmic Difference) is used. It amplifies the difference between the corrupted and uncorrupted pixels in ROAD. It works in two stages; it detects the noisy pixels from the degraded image and utilizes the edge preserving regularization method. It requires high computational time though it removes the random valued impulse noise at noise density below 60%.

Decision based algorithm is used to remove a random value impulse noise. It includes two steps; in first stage ROAD algorithm is used to identify the corrupted pixel. In the second stage adaptive median filtering is applied to remove a noisy pixel. The adaptive nature of the window blurring occurs in this method as the filter size is incremented and it is iterative process, hence requires high computational time. The above algorithms are confined to low noise density but suffers drastically at high noise density. So to preserve edge and to give better PSNR a new algorithm is proposed. ROAD algorithm is used to detect corrupted pixels and Trimmed Global Mean Filter is used to process a corrupted pixel with a constant window size.

3. RESEARCH METHODOLOGY

3.1 ROAD (Rank Ordered Absolute Difference) Algorithm

The local image statistic called ROAD proposed in [8] is reviewed. Let $a = a_1, a_2$ be the pixel location under consideration and $\Omega_a(N)$ be the set of point in $(2N+1) \times (2N+1)$ a neighbourhood centred at a for some positive integer. The $\Omega_a(N)$ is given by equation (1)

$$\Omega_a(N) = (a + (i,j) \quad -N \leq i,j \leq N \qquad (1)$$

Let us consider N=1. Hence Ω_a^0 represent the set of points in a [3×3] detected neighbourhood of s. Given by equation (2)

$$\Omega_a^0 = \Omega_a(1)/\{a\} \qquad (2)$$

For each point of b ϵ Ω_a^0 define $d_{a,b}$ as the absolute difference in intensity of the pixel between a and y. Absolute difference is given by equation (3)

$$d_{a,b} = |U_a - U_b| \qquad (3)$$

Sort the d_{ab} value in increasing order and define the ROAD by using equation (4)

$$ROAD_m(a) = \sum_i r_i(a) \qquad 1 < i < m \qquad (4)$$

Where $2 \leq m \leq (2N+1)^2 - 1$ & $r_i(a)$ is the smallest $d_{a,b}$ for $Y \epsilon \epsilon \Omega_a^0$

Let suppose for N=1 and for m=4, ROAD provides how close the current pixel value to its 4 closest neighbours in [3×3] window. The corrupted pixel will vary greatly in intensity from most or all the neighbouring pixels as per the logic under this statistic, so ROAD value will be larger and for uncorrupted pixel which belongs to actual image intensity should have half the neighbouring pixel of similar intensity, so ROAD value will be smaller. ROAD value can be used to detect a pixels corrupted by impulse noise by setting a certain threshold value. If the ROAD value is greater than threshold the pixel is corrupted otherwise pixel in uncorrupted. It is suggested in [25] to use a [3×3] window and m=4 for noise density less than 25% otherwise [5×5] window and m=12. Hence the ROAD algorithm gives information about the corrupted and non-corrupted pixels.

3.2 Trimmed Global Mean (TGM) Filter

In this stage, the corrupted pixels are detected by the algorithm. The pixel is uncorrupted if the processing pixels suppose P (i, j) is between 0 and 1. It is corrupted pixels if the P (i, j) is 0 or 1. We select a window of N X N for corrupted pixels and all uncorrupted pixels are removed from the selected window. The remaining pixels are arranged in increasing order and its median is figured out. The processing pixels are than replaced with the median value. if entire pixels are corrupted in the selected window then trimmed global mean value is replaced for the processing pixel. In this method all the corrupted pixels from the whole image are removed and mean of the remaining pixels is obtained and replaced with the processing pixels.

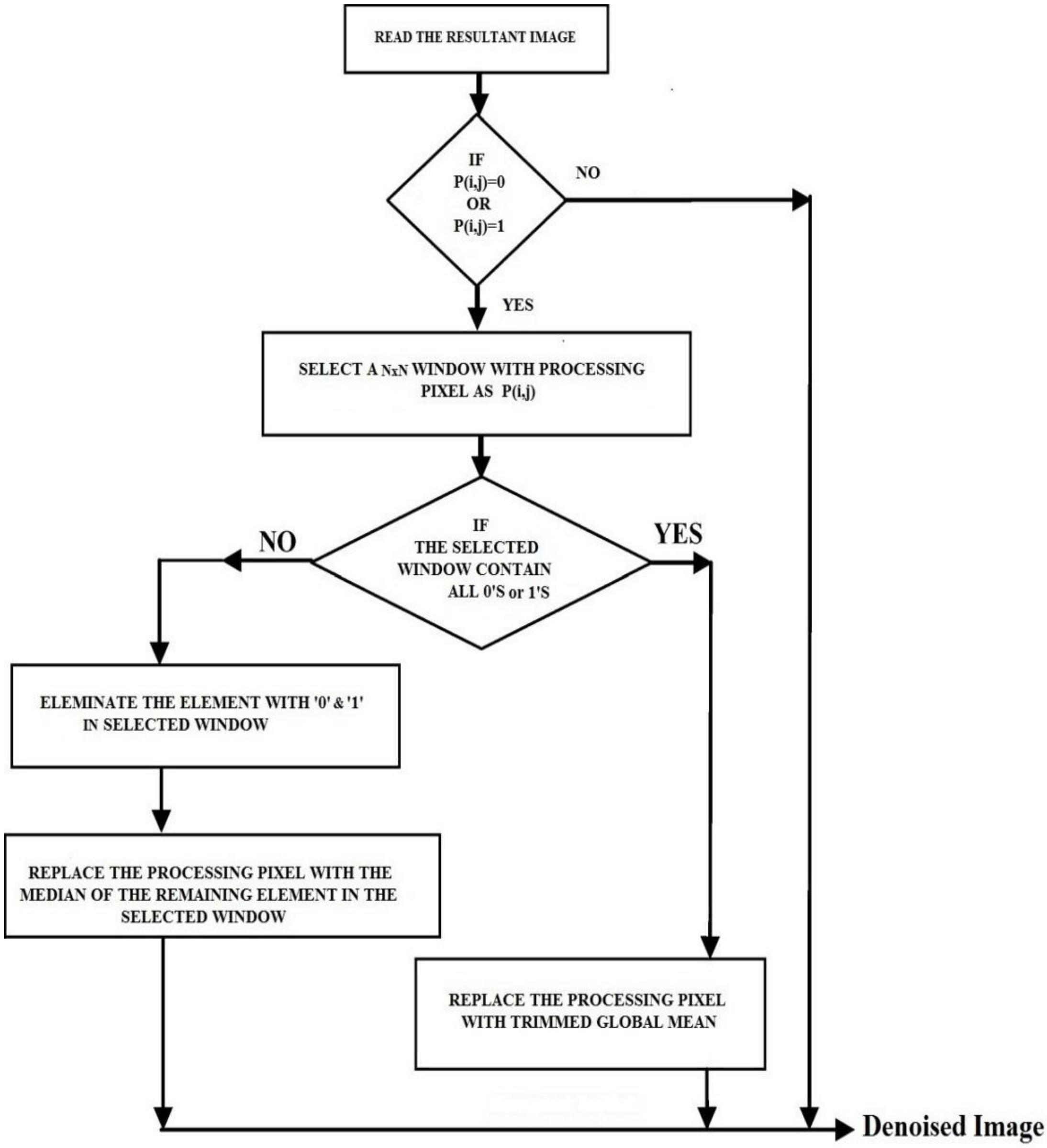

Figure 1: Flowchart of Trimmed global mean filter.

3.3 Introducing ROAD with Trimmed Global Mean (TGM) filter

A two stages algorithm is introduced namely the Detection Stage and the filtering stage as under: -

3.3.1 Detection Stage

Let O be the noisy image of size m x n, O (i, j) is a gray level value at pixel location (i, j) and W be the detection window of size w. O_w centred at O (i, j), where w= N+1 and initially N=1.The pixels in the detection window centred at O (i, j) is given by equation (5).

$$D = O(i+K, j+I) \quad -N \leq K, I \leq N \qquad (5)$$

The absolute difference of the processing pixel with the surrounding pixel in selected window is given by D in equation (6).

$$D = |O(i+K, j+I) - O(i,j)| \qquad (6)$$

The array D is sorted and the sum of m smallest absolute differences are obtained and this define the ROAD given by equation (7).

$$ROAD_m = \sum D(m) \qquad 2 \leq m \leq (2N+1)^2 - 1) \qquad (7)$$

The ROAD value obtained is compared with predefined threshold value (T). If ROAD value is greater than threshold then it is corrupted pixel and if ROAD value is lesser than threshold then it is uncorrupted pixels. From this condition we generate binary image in which if the processing pixel is X (i, j) is corrupted than we put 0 otherwise 1

$$B = \begin{Bmatrix} 1 & For\ ROAD(i,j) < T \\ 0 & For\ ROAD(i,j) > T \end{Bmatrix} \quad (8)$$

The above process is repeated for whole image.

3.3.2 Filtering Stage

In the filtering stage, the desired resulting image is obtained by element wise multiplication of binary image to noisy image. Resultant image is denoted as P of size m x n and given by equation (9)

$$P(i,j) = O(i,j) \times B(i,j) \quad (9)$$

Apply the trimmed global mean filter over the resultant image as given in figure 1.

4. RESULTS AND DISCUSSIONS

In this section we compare our method with various other methods to check noise detection and image restoration capability. The performance of all methods is compared quantitatively by using peak signal to noise ratio (PSNR). Which is given by equation (10)

$$PSNR(dB) = 10 * log_{10}(255 \times 255)/MSE \quad (10)$$

Where MSE is a mean square error between the denoised image (f_i) and original image (g_i).MSE is given by equation (11)

$$\mathrm{MSE} = \frac{1}{\mathrm{M}} * \sum_i (g_i - f_i)^2 \log_{10}(255 \times 255)/\mathrm{MSE} \quad (11)$$

For three images, we list the PSNR value for various filters with different noise density in Table I. ROAD value is used to detect noisy pixels in proposed algorithm based on the concept that the corrupted pixels will vary greatly in intensity from most of their neighbouring pixels. The intensity of actual pixels of the image is least half their neighbouring pixels.

The corrupted pixels in the original image can be tracked by varying threshold value. As given in [25] , we see that the mean ROAD value are near 1 for 3×3 detection window when noise density is less than 25% and 2.4 for 5×5 detection window, when noise density is greater than 25%. For 3x3 selected window, the threshold we have is [1.09-1.69] and for 5x5 window is [3.69-5.09].Trimmed global mean filter is used in the filtering stage in which the corrupted pixels are replaced by the median of uncorrupted pixels in the selected window and when the median value itself a corrupted then corrupted or processing pixel is replaced by trimmed global mean. Sometimes impulse are clump together in original image. Trimmed global mean is capable of removing that noise at high density satisfactorily.

4.1 Random Valued Impulse Noise

We added a random valued impulse noise in the standard image of Baboon, Bridge and Pentagon of 256x256. All three images are corrupted by 20%, 40% and 60% random valued impulse noise.

The proposed algorithm is applied over the images corrupted by impulse random valued noise. Results after applying the proposed algorithm on corrupted images are shown in Table 1. At 20% impulse noise the proposed algorithm give a maximum of 6dB increase in PSNR in baboon image from ROLD-EPR algorithm. At 40% impulse noise the proposed algorithm give a maximum of 31.28 of PSNR for pentagon image. At higher noise density (60%) proposed algorithm gives better PSNR; for baboon image PSNR is 24.57, for bridge image PSNR is 24.42 and for pentagon 28.23. This shows that proposed algorithm give better performance from standard filters.

5. CONCLUSION

After detailed analysis, it has been observed that the PSNR results achieved for the proposed algorithm are far better from standard algorithm. It provides a 30db PSNR for standard images. It is a simple algorithm used to remove various types of degradation like stripes, scratches, blotches and streaks. The algorithm uses [3x3] selective window ensuring fast algorithm. It doesn't include a iterative process which is usually time consuming due to computational processing. In future, a better algorithm can be implemented to detect the noisy pixels. ROLD is one of the effective detection algorithm expected to provide better results.

Table I: Comparison for restoration result in PSNR (dB) for image corrupted with random valued impulse noise

	Baboon Image			Bridge Image			Pentagon Image		
METHODS	20%	40%	60%	20%	40%	60%	20%	40%	60%
Median Filter [23]	22.52	20.65	19.36	25.04	22.17	19.36	28.29	25.16	23.41
ROAD-EPR [21]	24.24	21.53	19.96	27.42	24.52	22.04	30.35	30.35	25.01
ROLD-EPR [21]	24.49	21.92	20.38	27.86	24.79	22.59	30.73	30.73	25.7
ROAD-TGM	**30.79**	**27.21**	**24.57**	**31.79**	**27.72**	**24.42**	**35.44**	**31.28**	**28.23**

6. REFERENCES

[1] Chan, R.H. et al, (2004). "An iterative procedure for removing random-valued impulse noise", *IEEE Signal Process. Lett.*, Vol. 11, no. 12, pp. 921–924.

[2] Chen, T. et al, (2001b). "Space variant median filters for the restoration of impulse noise corrupted images," *IEEE Trans. Circuits Syst. II,Analog Digit. Signal Process.*, Vol. 48, no. 8, pp. 784–789.

[3] Luo, W. (2005). "A new efficient impulse detection algorithm for the removal of impulse noise", *IEICE Trans. Fundam.*, Vol. E88-A, no. 10, pp. 2579–2586.

[4] Kokaram, A.C. et al, (1995). "Detection of missing data in image sequences", *IEEE Transaction on image processing*, Vol. 4, no. 11, pp. 1496-1508.

[5] Srinivasan, K.S. et al, (2007). "A New Fast and Efficient Decision-Based Algorithm for Removal of High-Density Impulse Noise", *IEEE signal processing letter*, Vol. 14, no. 3, pp. 189-192.

[6] Pratt, W.K. (1975). "Median filtering", *Tech. Rep., Image Proc. Inst., Univ., Southern California, Los Angeles*.

[7] Vijaykumar, V.R. (2010). "Detection based adaptive median filter to remove blotches, scratches, streaks, stripes and impulse noise in images", *Proceedings of 2010 IEEE 17th International conference on image processing*, pp. 117-120.

[8] Garnett, R. et al, (2005). "A universal noise removal algorithm with impulse detector", *IEEE transaction on image processing*, Vol. 14, no. 11, pp. 1-7.

[9] Chen, T. et al, (2001a). "Adaptive impulse detection using center-weighted median filters", *IEEE Signal Process. Lett.*, Vol. 8, no. 1, pp. 1–3

[10] Crnojevic´ V. et al, (2004). "Advanced impulse detection based on pixel-wise MAD", *IEEE Signal Process. Lett.*, Vol. 11, no. 7, pp. 589–592.

[11] Tomasi, C. et al, (1998). "Bilateral filtering for colour and gray images", *Sixth International Conference on Computer Vision,* pp. 839-846.

[12] Nadenau, M.J. et al, (1996). "Blotches and scratch detection in image sequence based on rank ordered differences", *proceedings of Int Workshop on time varying image processing and moving object recognition*, Vol. 6, pp. 1-7.

[13] Subg-Jea, K. et al, (1991). "Center Weighted Median Filters and Their applications to image enhancement", *IEEE Transactions on Circuits and Systems*, Vol. 13, pp. 583-598.

[14] Abreu, E. et al, (1996a). "A simple method for the restoration of image corrupted by streaks", Proc. IEEE International Symposium on circuit and system, Atlanta, Vol. 2, pp. 730-733.

[15] Dong, Y. et al, (2007). "A detection statistic for random valued impulse noise", IEEE transaction on image processing, Vol. 16, no. 4, pp. 1112-1120.

[16] Aiswarya, K. et al, (2010). "A new and efficient algorithm for the removal of high density salt and pepper noise in images and videos", in second international conference on computer modeling and simulation, Vol. 4, pp. 409-413.

[17] Wang, Z. et al, (1999). "Progressive switching median filter for the removal of impulse noise from highly corrupted images", *IEEE Trans.Circuits Syst. II, Analog Digit. Signal Process.*, Vol. 46, no. 1, pp. 78–80.

[18] Balasubramanian, S. et al, (2009). "An efficient Nonlinear cascade filtering algorithm for removal of high density salt and pepper noise in image and video sequence", Intl Conf on control, Automation, communication and Energy Conservation, pp. 1-6

[19] Pomalaza-Racz C.A. et al, (1984). "An adaptive nonlinear edge preserving filter", *IEEE Trans. Acoust., Speech, Signal Process.,* Vol. ASSP-32, pp. 571–576.

[20] Hwang, H. et al, (1995). "Adaptive Median Filter: New Algorithms and Results", *IEEE transaction on image processing*, Vol. 4, no. 4, pp. 499-502.

[21] Veerakumar, T. (2012). " An approach to minimize very high density salt and pepper noise through trimmed global mean" International journal of computer application, Vol. 39, pp. 29-33.

[22] Gonzalez, R.C. et al, (2002). Digital image processing, Englewood cliffs, NJ: Prentice- Hall.

[23] Tomasi, C. et al, (1998). "Bilateral filtering for colour and gray images", *Sixth International Conference on Computer Vision,* pp. 839-846.

[24] Chan, R.H. et al, (2005). "Salt-and-pepper noise removal by median-type noise detectors and detail-preserving regularization", *IEEE Trans. Image Process.*, Vol. 14, no. 10, pp. 1479–1485.

[25] Chen, T. et al, (1999). "Tri-state median filter for image denoising", *IEEE Trans. Image Process.*, Vol. 8, no. 12, pp. 1834–1838.