An Efficient Decision based Multistage Median Filter for Reducing Impulse Noise from Blood Smear Malaria Images

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***Abstract**: Microscopic imaging method is used to improve the capability to understand and examine the microscopic world. The image generated by the microscope generally gets corrupted or distorted by impulse (salt and pepper) noise. In such cases, microscopic image processing methods are used to process, analyze, and represent the images obtained from a microscope. The impulse noise gets into the image due to sensors used in a digital microscope. This gives rise to difficulties for the classification of blood cells. In this paper, an Efficient Decision-based Multistage Median Filter (EDMMF) is suggested which is used to generate a low noise high contrast image from the acquired microscopic image using microscopic digital image processing tools. Standard and Modified filters can handle low noise levels but fail for higher ones. The EDMMF algorithm is a multistage combinational use of Morphological filter, adaptive median filter, and Improved Median filter. This filter decreases the noise maintaining the image details and the edges. For noise level in digital images less than 48%, Morphological and Efficient median filter used, whereas for higher noise levels efficient median filter used. The proposed EDMMF filter has been effectively applied to noisy microscopic malaria-infected thin blood smears. The experimental results proved that the suggested method excels in terms of Peak Signal to Noise Ratio (PSNR) and Mean Square Error (MSE) over existing versions of the Median filter.*

***Keywords**:*Falciparum Malaria, Impulse Noise, Multistage Filter Algorithm.

1. Introduction

In 2019, WHO released the World Malaria Report, which says, around 228 million people were found malaria-infected and approximately 405,000 lost their lives [1]. It is also estimated that 67% of the dead are children under the age of five [1]. Malaria-infected images areanalyzed usingvarious digital image processing techniques. It plays a major part in diagnosis of disease. Complete diagnosis depends on image quality; therefore, any decrease in image quality can lead to poor disease diagnosis. Images are damaged mainly due to the noise that often occurs on the image acquisition stage. The commonly encountered noise in microscopic images is in the form of randomly spread black and white dots, called Salt &Pepper noise or impulse noise. In the presence of such corruption, it is difficult to identify the elements of the real image or to distinguish the infected area[2]. Several filtering techniques have been used to reduce salt & pepper noise; most of them adopted the standard and modified versions of the median filter.

Median filter is a well-known order-statistical filter, which converts the pixel value by a median value of the adjacent gray levels of that pixel [3]. It is a useful non-linear image smoothening and enhancement method. For high noise densities, the performance of the median filter decreases, where it becomes blurred for large window sizes, and for small ones' insufficient noise is reduced [3].

The adaptive median filter has an adjustable window size which reduces impulse noise with great potential[4]. In this filter, noisy pixels are identified by comparing each pixel in the image with pixels existing in the same filter window. If this pixel is different from them, it is marked as a noisy pixel. In such a manner, all corrupted pixels are changed by the median value of the pixels

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in the vicinity of that window. At high ratios of noise, the window size needs to be increased also edge loss and blurring occur often because of which itreplaces a far pixel of the very different property with a noisy one[4].

2. Related Work

The most important stage in automatic malaria detection in blood smear images is image filtering, which removes impulse noise present in blood smear images. Previously, a lot of study is done on the probability of removing impulse noise in blood smear images. The following section reviews number of studies.

Sanjay Nag and S. K. Bandyopadhyay in [5] proposed an approach thateliminated impulse noise by the use of a median filter with a 3x3 kernel window.S. L. Varma and S. S. Chavan used a simple pixel replacement strategy employed to remove label artifacts[6]. Damandeep Kaur and Gurjot Kaur Walia proposed an approach to detect and classify malaria parasites[7]. The malaria-infected microscopic images are first filtered using spatial filtering followedby Ant Colony Optimization to retain the edges of the image. Lorenzoet al. in [8] converted images to HIS color space and then the intensity component was filtered using [3x3] median filter toremove noise. Also, a morphological top-hat operationwas used to adjust illumination balance. Sadiq et al. proposed the selection of appropriate features with Z-score for the detection of malaria-infected erythrocytes using supervised learning [9]. The combination of median and Gaussian filter was used as a preprocessing step to remove noise reflected by overlapping andimpulse noise. In addition to that, canny filters were used to maintain continuous edges of RBCs.Kanojia et al. identified that a 5x5 kernel of nonlinear median filter gives the best noise reduction in grayscale images [10]. Penas and P. T. Riveraused the saturation channel of HSV color space for preprocessing [11]. Image opening and closing was performed on the saturation component of image. This step confirms that impulse noise was removed. The problem of illumination was corrected by Devi et al. in [12] by using the grey world normalization method.The normalized image was thentreated by an adaptive filter to remove noise.Ghosh et al. used a Laplacian filter on microscopic images [13]. This makes the cell boundaries sharp. After that, the stained regions were identified by convertingthe sharpened image to HSI (hue, saturation, and intensity) color format.Devi et al. first obtained the normalized image by gray world normalization technique to rectify the illumination problem in [14]. The author then used the standard median filter with a window size of 5x5 to reduce the noise from the image. Somasekar et al. proposed a method to segment infected-erythrocytes for the detection of malaria [15]. The author used an adaptive median filter followed by illumination correction. In this algorithm, the window size used was 3x3, and the maximum window size used was 7. Arco et al. proposed an approach to automatically detect malaria-infected erythrocyte using morphological operations [16]. They had used spatial filtering and adaptive histogram equalization as a pre-processing stage. A Gaussian low pass filter wasappliedto the noisy image to minimize the effect of noise. This process makes the image brighter than the original image. Tsai et al. in [17]removed noise from the image using a mean filter.Hung et al. in [18] used the mean filter to remove impulse noise in the image. Tomari et al. proposed a method to classify the red blood cell as normal and malaria-infected in blood smear images [19]. Here author used three methods as morphological operations, Connected Component Labelling (CCL), and bounding box filter to clear away the redundant items. A sequence performing twice of Erosion, twice of Dilation, and contour filling algorithm is used to decrease the small noise and holes inside the cell. Chen et al in [18] utilized mathematical morphology to remove noise and smooth the edges of the object. Gitonga et al. in [20]used median filter with kernel size of 5x5 to enhance the noisy image. Das et al. proposed a machine-based investigative method for automated malaria parasite by means of light microscopic images [21]. Here geometric mean filter was applied on the gray image of illumination corrected image.S.S.Savkare and S.P.Naroteused a median filter of size 3x3 to eliminate unwanted pixels [22] [23]. Smoothening and edge enhancement were done by employinga Laplacian filter with second-order derivative on grayscale images. Xiong et al. in [24] first represented the image in the HSV color space. The inverse of the value channel was then applied to the median filter to remove noise. Ross et al. used a 5x5 median filter, and morphological area closing filter to reduce impulse noise in the image [25].

Based on above survey, most of the researchers used Median and Adaptive Median filters to reduce impulse noise from the microscopicimages. In the case ofmedian filter, a clean pixel value can be changed with an impulse noisy pixel in [KxK] window, if the number of noisy pixels in that windowis greater than (KxK)/2. Also, the median filter changes the center pixel value with the median value of that window without verifying whether that pixel is clean or noisy. The size of the window in the median filter is fixed, whereas, in an adaptive median filter, the size of the filtering windowis not fixed. If the median value in the current window is found to be noisy in adaptive median filter, then its window size increases. When window size is reached its maximum value, and still median value in the current window is noisy, the adaptive median filter gives the original pixel value as output. And if the original pixel value, in this case, is noisy then the impulse noise is not removed from that window. To overcome the above shortcomings of median and adaptive median filter, Weyori, Benjamin Asubam in [26] suggested a method called improved median filtering algorithm to reduce impulse noise. The author first calculated the effective median value and changes the center pixel value of that windowby the calculated effective median value of that window, only if that center pixel value is noisy.Improved median filter in [26] is not efficient for low-density noise images whereas the median or adaptive median filter alone is not able to remove impulse noise from images with high-density noise. To overcome these limitations, a Decision Based Multistage Morphological Efficient Median Filter is suggested in this paper. The proposed filter is a multistage combinational use of Morphological filter, Adaptive Median filter, and Improved Median filter. This filter removes the impulse noise by maintaining the edges and details of the image. The proposed filter has been examined over highly corrupted malaria-infected blood images. The comparative results indicate a notable improvement in image quality especially for high densities of noise.

3. Proposed EDMMFmethod

The Decision Based Multistage Morphological Efficient Median Filter (EDMMF) is proposed to reduceimpulse noise in different noise density. The EDMMF first determines the noise percentage in an image, and based on this value, it uses one of the three multistage filters as:

1) 1%<= Noise<= 47%: Morphological and Efficient Median Filter.
2) 48%<= Noise<= 92%: Morphological and Adaptive Median Filter.
3) 93%<= Noise<= 99%: Improved/Efficient Median Filter.

Figure 1. shows the flowchart of the EDMMF method

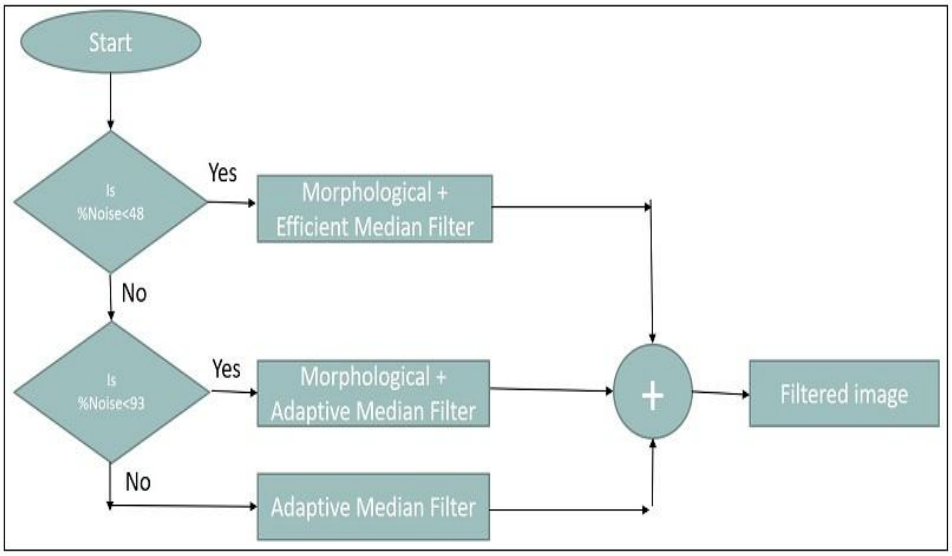

Figure 1: Flowchart for EDMMF.

4. Experimental Results

The EDMMF is tested against Median Filter, Adaptive Median Filter, Morphological Filter, Improved/Efficient Median Filter alone, combination of Morphological and Adaptive Median Filter and combination of Morphological and Efficient Median filter considering the peak signal to noise ratio (PSNR) and mean square error (MSE).Giemsa stained malaria blood smear images were collected from standard database available atCenter for Disease Control and Prevention, United States [27]. The size of the images is 300x300 pixels. The experiments are conducted with the help of Intel 7th generation i5-7200 central processing unit, having clock speed of 2.50 GHz and 8GB DDR4 RAM using MATLAB R2018a environment.

The above-mentioned parameter can be defined in eq.(i) and eq.(ii) as follows:

$$PSNR = 10\ log_{10}\left[\frac{\max\ O(i,j)^2}{\frac{1}{mn}\sum_{x=0}^{m-1}\sum_{y=0}^{n-1}[O(i,j)-F(i,j)]^2}\right] \text{(i)}$$

$$MSE = \frac{\sum_{x=0}^{m-1}\sum_{y=0}^{n-1}[O(i,j)-F(i,j)]^2}{mn} \text{(ii)}$$

where$O(i,j)$ is Original noise free image and $F(i,j)$ is filtered image.

For superior performance, the peak signal to noise ratio should be as high as possible, while the mean square error should be as low as possible. The percentage of noise in the image is varied from 1% to 99% and the graph of PSNR versus Percentage Noise and MSE versus Percentage Noise of considered filters were plotted.

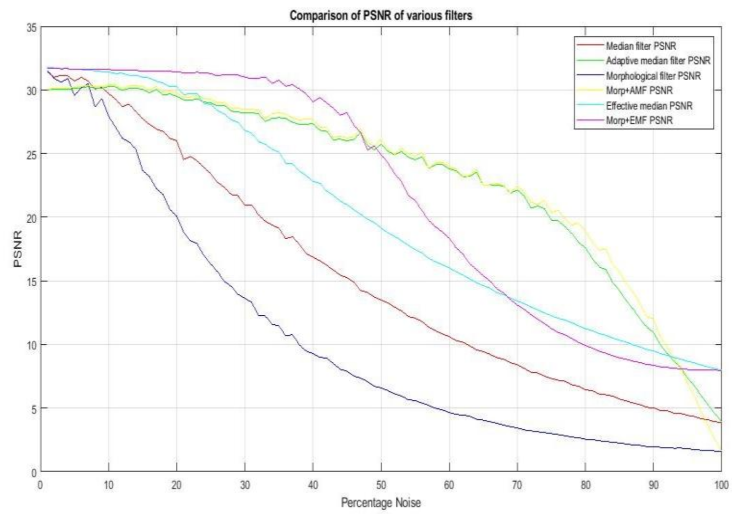

Figure 2: Graph of PSNR v/s Noise.

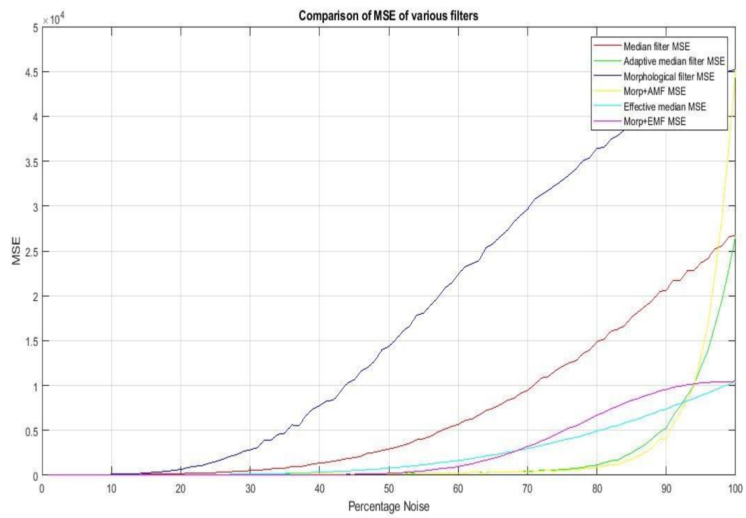

Figure 3: Graph of MSE v/s Noise.

Table 1. Comparison of PSNR and MSE of different filters with Noise=10%.

Filtering Technique	MSE	RMSE	PSNR	SNR
Median Filter	69.2197	8.3198	29.7625	10.5079
Adaptive Median Filter	62.3401	7.8956	30.2171	11.4203
Morphological Filter	105.1182	10.2527	27.9480	6.8528
Morph+AMF	60.1591	7.7562	30.3718	11.7215
Efficient Median Filter	46.9115	6.8492	31.4520	13.8917
Morph+EMF	45.2884	6.7297	31.6049	14.1879

Table 2. Comparison of PSNR and MSE of differentfilters withNoise=47%.

Filtering Technique	MSE	RMSE	PSNR	SNR
Median Filter	2370.7369	48.6902	14.4160	-20.5339
Adaptive Median Filter	186.1879	13.6451	25.4653	1.8989
Morphological Filter	12388.3322	111.3029	7.2347	-36.9445
Morph+AMF	173.3049	13.1645	25.7767	2.5017
Efficient Median Filter	634.2888	25.1851	20.1419	-8.9445
Morph+EMF	151.2079	12.2967	26.3691	3.6533

Table 3. Comparison of PSNR and MSE of different filters withNoise=48%.

Filtering Technique	MSE	RMSE	PSNR	SNR
Median Filter	2594.0578	50.9319	14.0250	-21.3518
Adaptive Median Filter	166.5584	12.9058	25.9491	2.8706
Morphological Filter	13020.4291	114.107	7.0185	-37.5164
Morph+AMF	160.3082	12.6613	26.1152	3.1806
Efficient Median Filter	688.7773	26.2446	19.7840	-9.6809
Morph+EMF	178.1542	13.3474	25.6568	2.2188

Table 4. Comparison of PSNR and MSE of different filters withNoise=92%.

Filtering Technique	MSE	RMSE	PSNR	SNR
Median Filter	21951.0015	148.1587	4.7503	-43.5541
Adaptive Median Filter	7724.5068	87.8892	9.2861	-31.6383
Morphological Filter	42243.8954	205.5332	1.9072	-59.1075
Morph+AMF	6965.9493	83.4623	9.7350	-30.8207
Efficient Median Filter	8041.1089	89.6722	9.1116	-34.4452
Morph+EMF	9974.1203	99.8705	8.1761	-37.5014

Table 5. Comparison of PSNR and MSE of different filters withNoise=93%.

Filtering Technique	MSE	RMSE	PSNR	SNR
Median Filter	22694.9538	150.6484	4.6055	-43.9808
Adaptive Median Filter	8967.7074	94.6980	8.6380	-33.1357
Morphological Filter	42616.9573	206.4387	1.8690	-59.3733
Morph+AMF	8586.6434	92.6641	8.8266	-32.9209
Efficient Median Filter	8284.7375	91.0205	8.9820	-34.8473
Morph+EMF	10039.8772	100.1992	8.1475	-37.6067

Table 6. Comparison of PSNR and MSE of different filters withNoise=99%.

Filtering Technique	MSE	RMSE	PSNR	SNR
Median Filter	26162.8962	161.7495	3.9879	-46.0746
Adaptive Median Filter	22859.2144	151.1926	4.5742	-44.0690
Morphological Filter	44942.2372	211.9958	1.6383	-61.8971
Morph+AMF	36748.6158	191.6993	2.5124	-54.2206
Efficient Median Filter	10142.3084	100.7090	8.1034	-37.7584
Morph+EMF	10461.7045	102.2825	7.9688	-38.2418

5. Result and Discussion

All the filters mentioned in the literature survey fail to handle noise in highly corrupted images where noise levels may reach 90%. Better image quality implies, the filter should give utmost value of PSNR and the lowermost value of MSE. Fig.2 and 3 and Tables 1, 2, 3, 4, 5, and 6, depictbetter image quality has been achieved by using combination of Morphological and Efficient Median filter up to 47% noise, combination of Morphological and Adaptive Median filter from 48% to 92% noise, and the Efficient Median filter above 92% noise. With this information, we proposed EDMMF which gives better image quality for all variation of noise density.

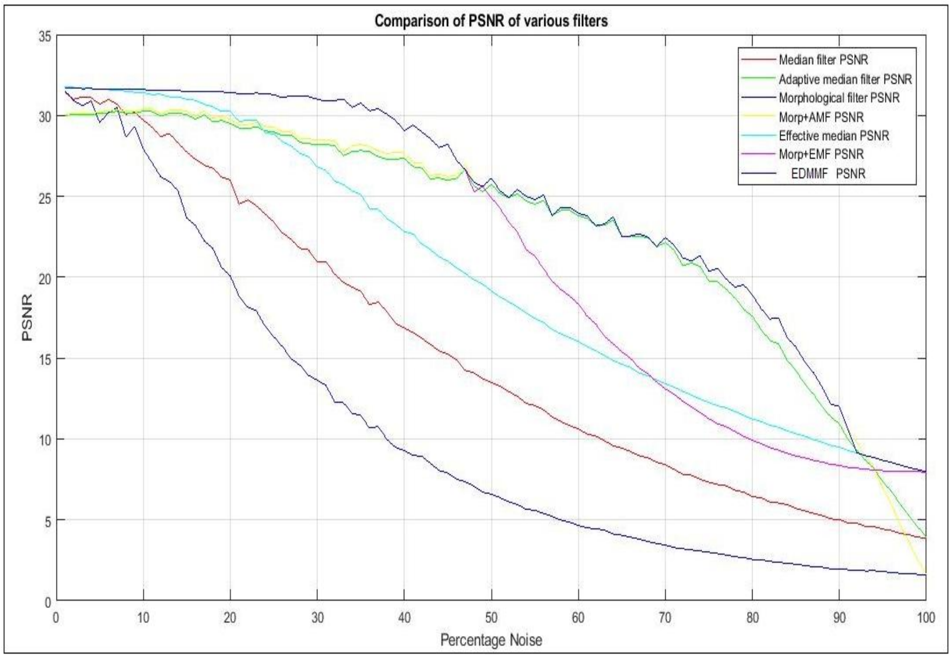

Figure 4: PSNR Comparison of variousfilters with EDMMF.

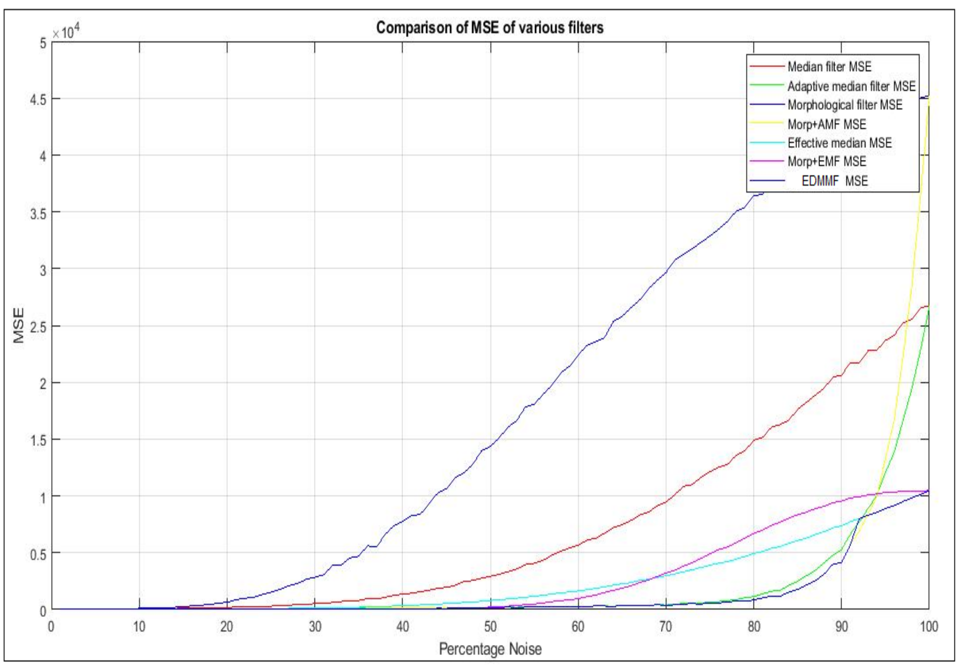

Figure 5: MSE Comparison of variousfilters with EDMMF.

Figures 4 and 5 show a graph of PSNR versus Percentage Noise and MSE versus Percentage Noise of considered state-of-the-art filters compared with EDMMF. It shows that EDMMF gives the highest PSNR and the lowest MSE amongst considered state-of-the-art filters.

Figure 6 shows the comparative results of applying considered filters over blood images of malaria-infected smears, where the presented filter is denoted as EDMMF.

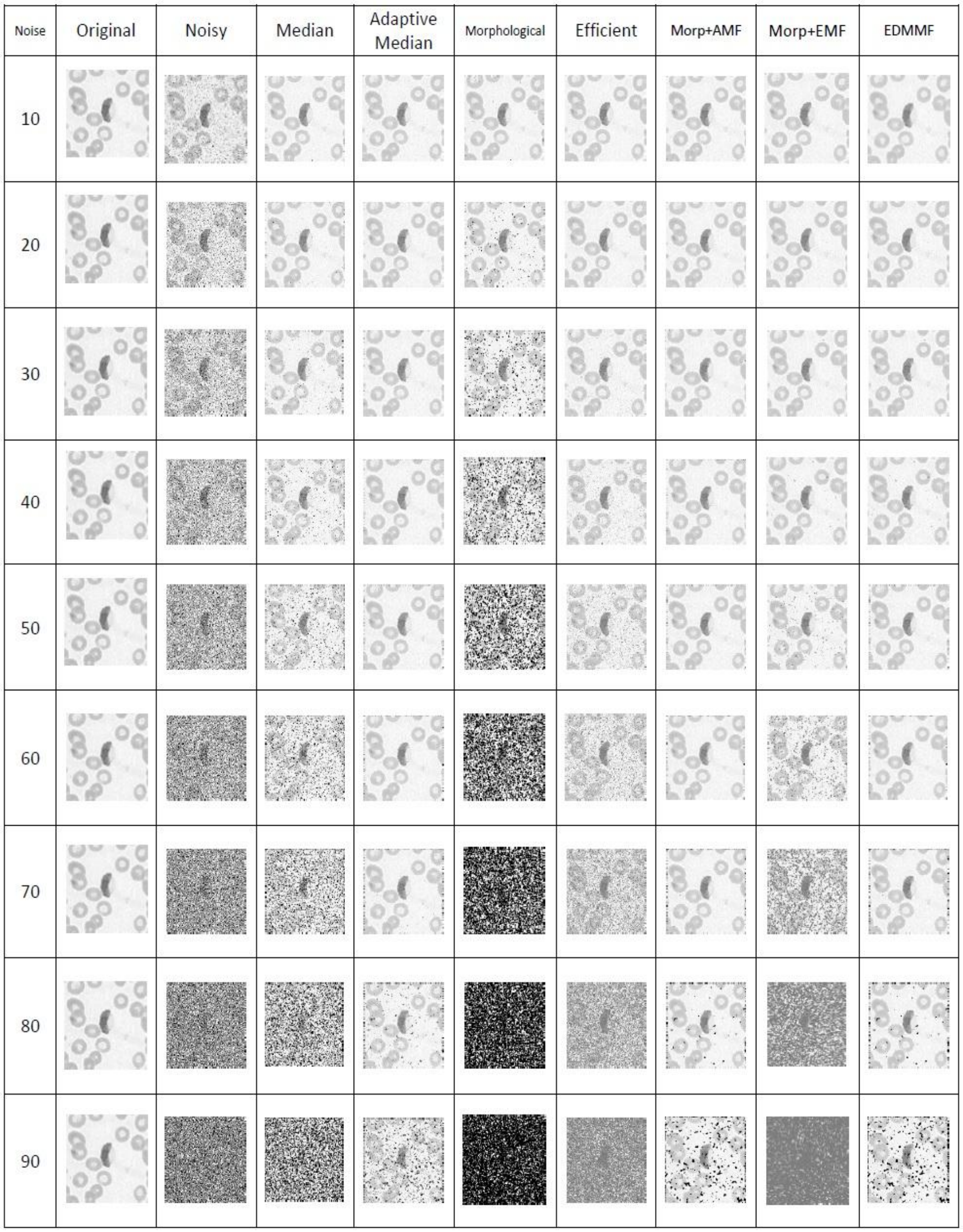

Figure 6: Filtered output of the microscopic blood image.

6. Conclusion

The proposed EDMMF algorithm removed impulse noise from the corruptedmalaria-infected images. From the quantitative result analysis, it is proved that the EDMMF method is better than the existing median and adaptive median filter in de-noising the microscopic blood smear images having noise levelsfrom 1% to 99%. The EDMMF algorithm produces better image quality than the existing median and adaptive median filter when applied to noisy images. Also, edge details and fine details in the filtered image are preserved by our suggested method. The suggested EDMMF can be used as a reliable pre-processing methodfor disease detection in microscopic medical images.

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