# Modified Hybrid Median Filter with Local Preserving for Removal of Low Density Random-Valued Impulse Noise in Images

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***Abstract*- Random-valued impulse noise has proven to be more difficult to remove from corrupted images than standard impulsive noise due to its random nature. Because standard impulse noise filters target the whole images pixels, useful image details and information may be loss after the filtering process. To filter the corrupted pixels and preserve important image details during filtering, it is vital to introduce local preserving to the filter. In this paper, a new filter for the removal of random-valued impulse noise in digital grayscale images is presented. The filter is made up of two different stages which is noise detection and filtering steps, in which the properties of the random-valued impulse noise and a modified hybrid median filter is used. This noise detection is based on the histogram information of the image corrupted by random-valued impulse noise to prevent the filtering of noise free image pixels. The filtering of the detected noisy pixels is performed afterwards using the modified hybrid median filter. By introducing a local preserving scheme to the modified hybrid median filter, the results obtained is shown to outperform the standard median filter as well as the modified hybrid median filter.***

***Keywords- random-valued impulse noise, hybrid median filter, local preserving, mean square error, peak signal-to-noise ratio.***

## I. INTRODUCTION

During the acquisition or transmission, digital images are susceptible to corruption by impulse noise due to errors generated in noisy sensors or communication channels [1]. The noise may seriously affect the performance of image processing technique [2]. Therefore, it is crucial to remove noise present in images before further processing such as image segmentation, object recognition, or edge detection. Typically, when images are corrupted by impulse noise, only a portion of pixels are changed depending on the noise density.

Some residue of noise will always be present in any electronic device that transmits or receives a signal. The goal of image denoising is to reduce noisy pixels from corrupted images as much as possible while retaining the original image details, information, and features.

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To this end, the use of noise filtering is introduced. Typically, the removal of impulse noise will result in the loss of finer details due to ineffective edge preservation [3]

A large number of two-staged filters have been proposed for removing impulse noise from corrupted images based on a modification of the standard median filter [4-11]. These filters take into account the image composition and noise presence before filtering the noisy image. Then the filtering process is applied only to the identified noisy pixels while leaving the original, noiseless pixels untampered. This method has been shown to be simple and more effective than uniformly applied methods such as the numerous modifications of the standard median filters.

In this paper, the focus is on random-valued impulse noise (RVIN) where the two noisy pixel values can be any number between the grey levels, as opposed to the salt and pepper impulse noise which are fixed at both 0 (black) and 255 (white). The removal of RVIN is relatively more difficult in comparison with salt and pepper impulse noise [12] since for the latter, the differences in gray levels between a noisy pixel and its noise-free neighbors are significant most of the times whereas in the case of RVIN, the noisy pixels are almost indistinguishable from the noiseless pixels.

In this study, an efficient median filter is proposed which is based on the method for removing random-valued impulse noise. It is a two-phase iterative method which is made up of the detection phase followed by the filtering phase. The local preserving scheme is introduced in the form of the detection phase to identify the pixels which are likely to be corrupted by noise. The following filtering phase then uses the information from the detection phase to filter out the noisy pixels while keeping the noise-free pixels untouched.

The rest of this paper is organized as follows. Section II describes the proposed method in detail which includes the working schemes of the local preserving as well as the filtering technique used to determine the new value which will replace the corrupted pixels. Section III discusses the experimental results which is separated into two types, the qualitative and quantitative results. Finally, the conclusion is given in Section IV.

## II. METHODOLOGY

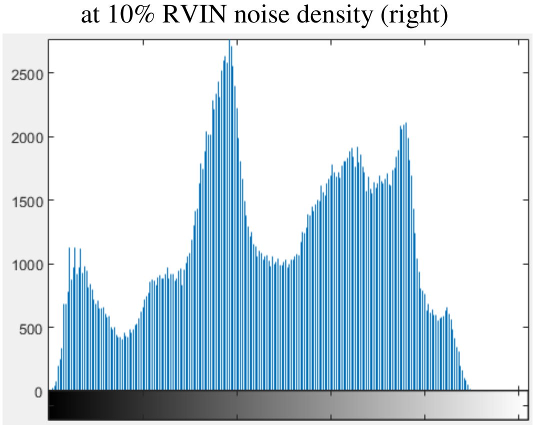
To achieve the objective of this paper, a local preserving scheme is first introduced into filter in the form of a noise detection phase to allow the filter to distinguish between noise and noise-free pixels in Part A. In Part B, a filtering scheme is executed on the image which targets only the nose pixels. Part C will measure the effectiveness of the noise reduction and detail preserving in filtering digital images.

### *A. Detection Phase*

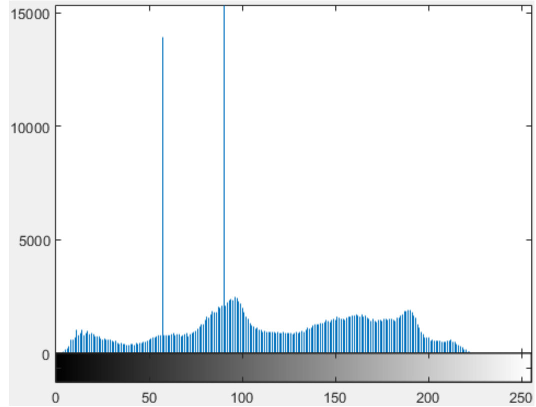
The median filter has been established as a reliable method to remove impulse noise without damaging the edge details [13]. However, typical median filters are implemented uniformly across the image and tends to modify both noise pixels and noise free pixels. As a result, this would inevitably alter the intensities and remove the image details contributed from uncorrupted pixels, and cause image quality degradation [14].

To protect the noise free pixels, the detection phase is first introduced before the filtering process in this proposed method. This enables the filter to differentiate between noisy and noise-free pixels and allows the finer image details and important image information to be preserved. Detection of RVIN is a little difficult because of its random nature [15]. Therefore, the detection phase is formulated by making use of the histogram information extracted from the corrupted RVIN image. Figure 1 shows original *pepper* image and the image after being corrupted with RVIN at 10% noise density.

Figure 1: Original *pepper* image (left) and corrupted image at 10% RVIN noise density (right)




(a)




(b)

Figure 2: Histogram of (a) original *pepper* image and (b) *pepper* image corrupted by RVIN at 10% noise density

Figure 2 shows the histogram of original *pepper* image and histogram of *pepper* image after being corrupted by RVIN at 10% noise density in Figure 1. From the histograms, it can be observed that there is a significant difference in the pixel composition and distribution as the corrupted image have two grey levels pixels abundantly higher than the rest of the grey levels. The two peak grey levels form an impulse in the histogram of the corrupted image, hence the impulse noise name.

Using the histogram information, the detection phase will first detect and evaluate the two peak grey levels by sorting and tallying the grey levels pixels count present in the images. The two grey levels with the highest pixel count as well as its' location will then be recorded and labeled as the noisy pixels. The subsequent filtering phase will make use of this information by only targeting the pixels with these two grey level values while leaving pixels with other grey levels untouched.

### *B. Modified Hybrid Median Filter*

For the filtering phase, the technique used is based on a modification of the hybrid median filter (MHMF) presented in [16] which operates on the same sliding window spatial filter that targets each pixel in a filtered image sequentially. The difference of the filter is that rather than using the targeted pixel as the third element, the median value of the sliding window is instead taken into account as depicted in Figure 3. The median of these 3 values is then saved as the new pixel value. For example, in a 3×3 image contains 9 pixels (in the square neighborhood) which must be ranked in the traditional method. In the modified hybrid median filter, each of the two groups contains only 3 pixels, and the final comparison involves only three values. This modified hybrid median filter overcomes the tendency of median and truncated median filters to erase lines which are narrower than the half width of the neighborhood and to round corners.

$$\begin{pmatrix} A & B & C \\ D & E & F \\ G & H & I \end{pmatrix}$$

$$h_1 = median(A, E, I)$$
$$h_2 = median(C, E, G)$$
$$h_3 = median(A, B, C, D, E, F, G, H, I)$$

$$New\ pixel\ value\ = median(h_1, h_2, h_3)$$

Figure 3: Elements in sliding window selection algorithm of the modified hybrid median filter

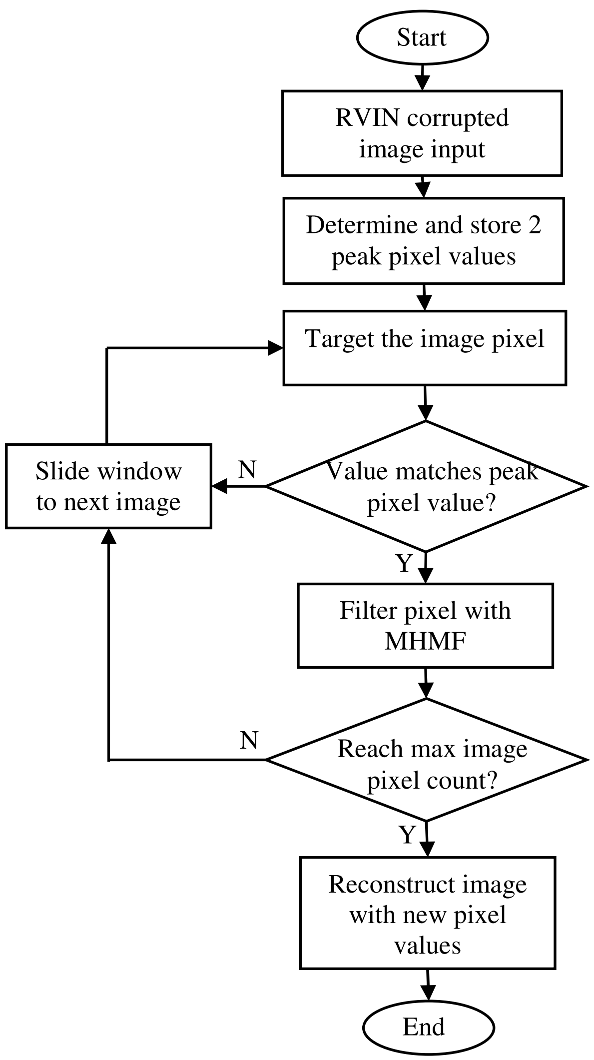



Figure 4: Flow chart of the modified hybrid median filter with local preserving

Figure 4 shows the flowchart of the modified hybrid median filter with the local preserving scheme introduced. At the start of the filter, an RVIN corrupted image serves as an input. The image would be processed for the two peak pixel values. The two values are then stored and treated as noise pixels. The filter then uses a sliding window mechanism, targeting the image pixel beginning from the top left pixel. The sliding window then evaluates the pixel to see if it matches one of the two noise pixel values. If it matches, the targeted pixel would be filtered with the modified hybrid median filter. If the targeted pixel does not match the two noise pixel values, the filter would leave the pixel as is and the sliding window would move on to target the adjacent pixel. This process is repeated until the pixel count of the filtered image has been reached. The image is then reconstructed with the new filtered pixel values.

### *C. Data Samples and Analysis*

The performance of the proposed filter will be evaluated and compared to the hybrid median filter in terms of the mean square error (MSE) and peak signal-to-noise ratio (PSNR) of the filtered image based on the original uncorrupted image. The proposed filter will use grayscale image to study the effectiveness of the filter as well as avoid any discrepancies when tested. The modified hybrid median filter will be implemented with the use of the MATLAB software and the included image processing toolbox. The noise type that would be used to test the performance of the proposed filter is RVIN.

$$MSE = \frac{\sum(S_{original} - S_{filtered})^2}{\sum^{1}} \quad (1)$$

$$PSNR = 10\log_{10}\left(\frac{256^2}{MSE}\right) \quad (2)$$

$S_{original}$ = Original image

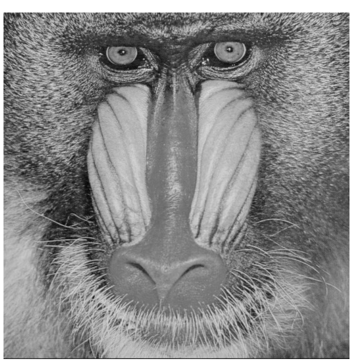
$S_{filtered}$ = Filtered image

Equations 1 and 2 are both used in the performance evaluation of the tested filters. The S in equation 1 represents the images with the original being the untampered image before noise injection and the filtered being the noise filtered image. The sum refers to the collective sum of the individual image pixel values referring to each of the two images. The MSE obtained using equation 1 is then used to calculate the PSNR with equation 2. The unit of PSNR is decibel (dB). A high PSNR value signifies a better image reproduction quality.

The grayscale images used in this study are acquired through the internet. The digital images used like the *rhino*, *village*, *baboon*, and *alley* images in Figure 5 are those that are commonly used in image processing research and studies. The original images are used as a benchmark to test the image reproduction qualities of the filters as well as used in the mean-square error and peak signal-to-noise ratio calculations. Since the images obtained are untampered and noise-free, the RVIN would need to be injected manually into the images to simulate the corruption of the image data.

*rhino*

*village*



*baboon*

*alley*

Figure 5: Examples of the original images used in the proposed filter's performance evaluation

The RVIN is simulated with the use the MATLAB software. The impulse-noise injection process operates on user-specified parameters and properties of the impulse noise like the noise type and noise density can be configured as need be. For this paper, the noise type is configured to RVIN with different noise densities.

Two noisy pixels' values are randomly distributed across the pixels of the image at the noise density levels specified. The same corrupted image is used for both the proposed filter with and without local preserving to avoid any discrepancies in the data. The noise injection is done with several iterations and varying noise densities across the different subject images used.

## III. RESULT AND DISCUSSION

This section is divided into two sections; qualitative results and quantitative results. The result of the proposed method is compared with the Modified Hybrid Median Filter without the Local Preserving schemes. The qualitative results will test the ability of the filter to reduce the RVIN pixels from the corrupted image as well as the image reproduction quality. It is based on the appearance of the image reproduced by the filter discernable to the naked eye. Next, the quantitative analysis of the results is performed. The quantitative will evaluate the filter's performance in terms of MSE and PSNR as this study requires more quantifiable results to accurately determine the performance of the filter along with the quantitative results.

### A. *Qualitative Results*

To better see the difference and significance of the noise reduction, the corrupted image injected with RVIN is first shown in relation to both the images reproduced by the filter with and without local preserving in Figure 6. The image reproduced without local preserving is noticeably blurrier than the one reproduced with local preserving. This is because the filter does not discriminate between noisy and noiseless pixels without local preserving and will filter any and all pixels in the image uniformly.

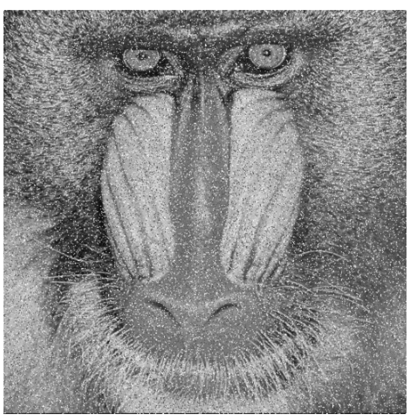
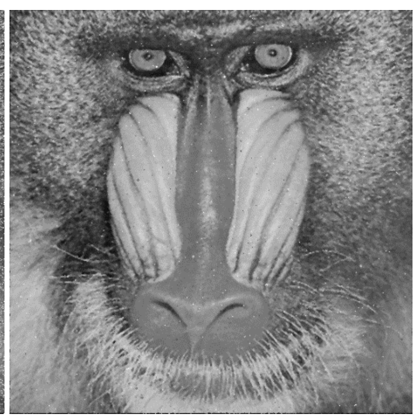
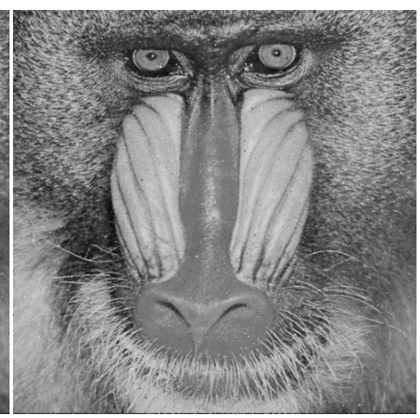
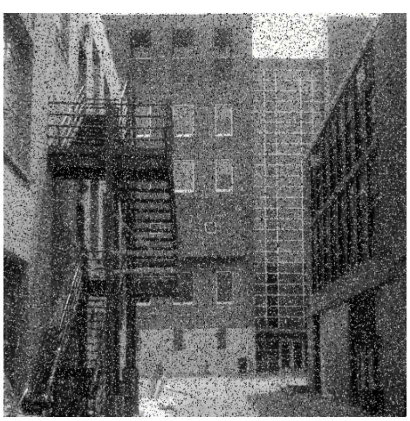
| ND (%) | RVIN corrupted original image | Image filtered without local preserving | Image filtered with local preserving |
|---|---|---|---|
| 5% |  |  |  |
| 10% |  |  |  |
| 15% |  |  |  |
| 20% |  |  |  |

Figure 6: Qualitative comparison of the filter performance between the hybrid median filter and the modified hybrid median filter at different noise densities percentage using images in Figure 5

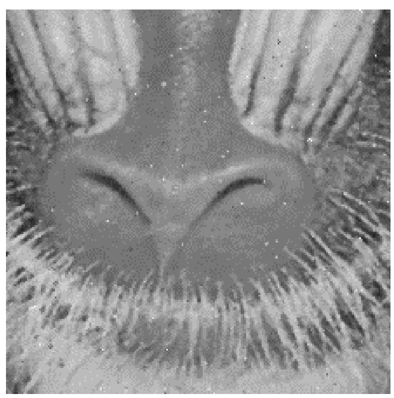
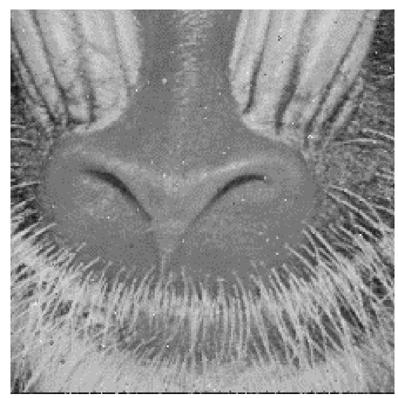
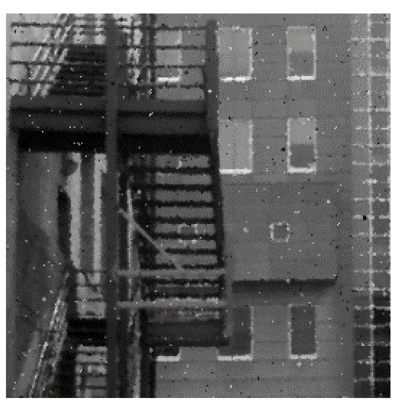
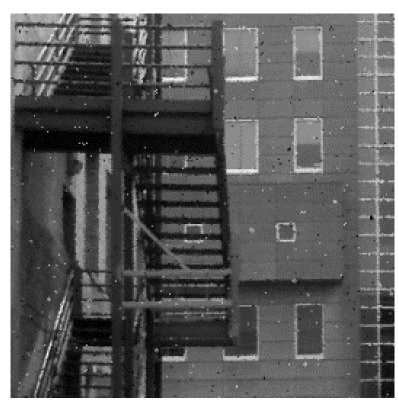
| ND (%) | Description | Image filtered without local preserving | Image filtered with local preserving |
|---|---|---|---|
| 5% | The rhino's horns and ears well as the grass are sharper as and well defined for the image processed with the proposed algorithm. |  |  |
| 10% | The whole building including the roof tiles, windows, and the bricks are sharper on the image processed with the proposed algorithm. |  |  |
| 15% | The baboon's nose and the cheeks as well as the individual whiskers of the image filtered without local preserving are blurrier compared to the image filtered with local preserving. |  |  |
| 20% | The windows outlines can still be made out to be straight and square and the stairs as well as the railing are sharper and clearer for the image processed with the proposed algorithm. |  |  |

Figure 7: A zoom-in of images from Figure 6 for qualitative comparison of the filter performance between the hybrid median filter and the modified hybrid median filter at different noise densities percentage

### B. *Quantitative Results*

Table 1: MSE and PSNR comparison for *rhino* image

| Noise Density (%) | Without local preserving | | With local preserving | |
|---|---|---|---|---|
| | MSE | PSNR | MSE | PSNR |
| 5 | 23.77 | 34.40 | **7.45** | **39.44** |
| 10 | 31.62 | 33.16 | **15.04** | **36.39** |
| 15 | 73.07 | 29.53 | **51.69** | **31.03** |
| 20 | 176.22 | 25.70 | **137.84** | **26.77** |

Table 2: MSE and PSNR comparison for *village* image

| Noise Density (%) | Without local preserving | | With local preserving | |
|---|---|---|---|---|
| | MSE | PSNR | MSE | PSNR |
| 5 | 51.67 | 31.03 | **11.61** | **37.52** |
| 10 | 112.55 | 27.65 | **59.01** | **30.45** |
| 15 | 109.86 | 27.76 | **66.75** | **29.92** |
| 20 | 158.46 | 26.17 | **110.79** | **27.72** |

Table 3: MSE and PSNR comparison for *baboon* image

| Noise Density (%) | Without local preserving | | With local preserving | |
|---|---|---|---|---|
| | MSE | PSNR | MSE | PSNR |
| 5 | 284.35 | 23.62 | **33.83** | **32.87** |
| 10 | 350.54 | 22.72 | **97.65** | **28.27** |
| 15 | 372.25 | 22.46 | **134.72** | **26.87** |
| 20 | 402.77 | 22.11 | **169.43** | **25.87** |

Table 4: MSE and PSNR comparison for *alley* image

| Noise Density (%) | Without local preserving | | With local preserving | |
|---|---|---|---|---|
| | MSE | PSNR | MSE | PSNR |
| 5 | 91.90 | 28.53 | **24.52** | **34.26** |
| 10 | 115.29 | 27.55 | **45.36** | **31.60** |
| 15 | 173.20 | 25.78 | **93.52** | **28.46** |
| 20 | 278.88 | 23.71 | **192.61** | **25.32** |

Referring to the results displayed in Tables 1 through 4, it can be observed that both the filters with and without local preserving performance worsen as the noise density increases. In each case however, the MSE of the proposed filter i.e. the Modified Hybrid Median Filter with Local Preserving is lower than the filter without local preserving while the PSNR is higher. The performance of filter without local preserving sharply declines as the noise density goes higher. Both the qualitative and quantitative results favor the filter with local preserving more compared to the filter without local preserving.

20 more different images are tested both with and without local preserving to further evaluate and confirm the robustness of the proposed filter and the average MSE and PSNR are then calculated from the results. Because of the nature of RVIN that randomly scatters noisy pixels in an image as well as the varying composition of different digital images, this is done to ensure that the filter with added local preserving performs better and is more competent than the filter without local preserving at any noise density.

Table 5: MSE and PSNR comparison for 20 images

| Noise Density (%) | Without local preserving | | With local preserving | |
|---|---|---|---|---|
| | MSE | PSNR | MSE | PSNR |
| 5 | 82.51 | 31.42 | **14.51** | **37.83** |
| 10 | 118.42 | 28.92 | **46.21** | **32.44** |
| 15 | 169.15 | 26.61 | **94.02** | **28.76** |
| 20 | 274.76 | 24.48 | **183.17** | **26.31** |

The cumulative results as seen in Table 5 proves that the filter with local preserving is consistently better than without local preserving as the MSE is lower and the PSNR is higher even at different noise densities. The quantitative results, along with the qualitative results, reinforce the notion that introducing local preserving to the modified hybrid median filter improves the filter noise reduction and image reproduction quality greatly.

## IV. CONCLUSION

This paper introduces a local preserving to a new modified hybrid median filter in the form of noise detection for the reduction of RVIN. From the results achieved, the implementation of the detection phase before filtering the RVIN from corrupted image has improved the filter performance considerably. The added noise detection helps the filter to differentiate between noisy and noiseless pixels.

This renders the filter more effective in preserving the useful details in the filtered image while maintaining the edges as well as enhances the image reproduction quality. At higher noise density however, the filter's performance decreases due to the higher count noisy pixels taken into account during the filtering phase. In future developments, several improvements could be made to the filter to better detect and discriminate the noisy pixels from noiseless pixels as well as reduce the noisy pixel residue after the filtering phase.

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