Study of hybrid median filter for the removal of various noises in digital image

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Abstract. The aim of this study is to construct a hybrid median filter using MATLAB and use that filter to remove impulse noise from an image, in order to produce an enhanced image. This is done in order to show how a hybrid median filter can be a more optimal option than a conventional median filter for removing impulse noise.

1. Introduction
An image is processed and stored in the memory once it is captured by a camera. The captured image can undergo some damage due to impulse noises. Impulse noises are short duration noises which degrade an image. They may occur due to various reasons such as atmospheric disturbances during image transmission, or switching sensor temperatures during acquisition, or due to some channel interference. Unlike Gaussian noise, impulse noise is random and it is uncorrelated to the image pixels. Hence, some pixels may be corrupted whereas some pixels may remain uncorrupted. Image Enhancement is a very important aspect of image processing. Denoising an image is a fundamental task to subsequent processing operations. Noise removal is necessary to maintain the quality of the image by preserving the details of that image. Image Filters produce an enhanced image by operating on the pixel values of the original image. Median Filter is a type of non-linear filter that can be used to remove impulse noise in an image. It works by taking the output at the centre as the median value of all the pixels in the neighbourhood. A hybrid median filter is an advanced version of the median filter that can remove impulse noise in the image as well as preserve the corners of the image.

2. Literature survey
2.1. Impulse noise
Impulse Noise can be classified into two types, namely – Salt and Pepper type and Random Valued type. Salt and Pepper type impulse noise is called so because this type of noise produces white and black dots in the image. The noisy pixels take either the pixel value of ‘0’ or the pixel value of ‘255’. In this type of noise, salt noise density and pepper noise density take a value of p/2 each, where the total noise density is given by p. In the case that salt noise density takes a different value p₁ from the pepper noise density p₂, then the total density is given by

\[ p = p_1 + p_2 [1]. \]
As opposed to Salt and Pepper noise, Random Valued Noise takes any value between 0 and 255. In this type of noise, the noisy pixels are distributed randomly over the entire image.

2.2. Filters

Spatial Filtering is done by taking a neighbourhood in the image and processing the pixel values of that neighbourhood to produce output in the centre pixel. The equation for spatial filtering is given by:

\[ g(x,y) = \sum \sum w(s,t) f(x+s, y+t) \]

Filters can be classified into two types:

i) Linear filters: Linear filtering is a technique in which the output pixel value is given by a linear combination of the input pixels from the neighbourhood. The equation for a linear combination is given by [2]:

\[ H(af+bg) = aH(f) + bH(g) \]

Noise can be removed using linear filters such as smoothing filters. This can be done by convolving the image with a mask that represents a low pass filter or an averaging filter. However, this might remain ineffective in the case that the noise non-additive or non-Gaussian. Besides, two dimensional images might have certain details such as edges which could be blurred out by using smoothing filters.

ii) Non-linear filters: They are called so since it does not function on a linear algorithm, instead it checks the value of each pixel and replaces it if it is a noisy value by using an estimate from the neighbouring pixels. The algorithm is non-linear because it looks at each data point and removes data that is recognized as noise. Non-Linear filters are also used in image restoration by estimating the clean or original image from the corrupted or noisy image.

3. Median filter

A median filter is a type of non-linear filter. It works by estimating the median value of the neighborhood pixels. It is effective in filtering because it removes noise while preserving edges of the image. The median is calculated by arranging the pixels of the neighborhood in either ascending or descending order and then taking the middle value as the output pixel. The best output from median filter is achieved when the noise percentage is less than 0.1%. The median filters can be applied repeatedly in the case than the noise percentage is more, since edges get degraded minimally. Median filters are also effective for the reason that it tends to preserve the boundaries in the image. It also preserves the brightness of the image and allows for pasteurization to occur from repeated application.

To run a median filter:

i. Consider all the pixels in the neighborhood of the image.

ii. Sort the pixels into numerical order based on their intensities.

iii. Replace the original value of the pixel with the median value of the neighborhood.
4. Hybrid median filter (HMF)

A hybrid median filter (HMF) ‘figure 1’ works by taking the median of various pixels in different neighborhood shapes, and in turn taking the median of the previously obtained median values and the original pixel value. The neighborhood shapes are taken straight and diagonally around the center pixel, i.e. in a ‘+’ and ‘x’ shape respectively. In comparison to a normal median filter, the hybrid median filter is better at preserving corner features. This is because it is a three-step ranking operation ‘figure 2’.

i. A window is selected depending on the image size, and two sub-windows are selected which are of the ‘x’ and ‘+’ shapes.

ii. The diagonal median (Mx) is calculated by arranging the pixels in either ascending or descending order.

iii. The horizontal-vertical median (M+) is calculated by arranging the pixels in either ascending or descending order.

iv. The output is calculated as the median between M+, Mx and the center pixel value.

One important factor in a hybrid median filter is also that it takes up less computational complexity. This is because it only operates on fewer pixels in a window as opposed to all the pixels in a square mask of the same size [2].

![Figure 1. Block diagram of restoration of image using HMF [2]](image1)

![Figure 2. Flow diagram for HMF](image2)
The drawbacks of conventional Arithmetic filters are that it leads to the blurring of the fine details in an image. Median filter can be used in place as it smoothens the image rather than blurring it. The hybrid median filter is more advantageous as compared to the conventional filters as it preserves corner details well and does not eliminate lines. The hybrid median filter works by convolving masks of 45° and 90° each on the image ‘figure 3’. These masks are used to determine the medians of the image, which is then used to compute the median with the center pixel value.

![Figure 3. Neighborhood masks](image)

The hybrid median filter can be implemented using the MATLAB software. An image is chosen to test the filter. It is first converted into a noisy image. The filter is then implemented by choosing a 3x3 window and then creating the 45° and 90° masks respectively. The noisy image is then passed through a ‘for’ loop that uses the two sub-windows in order to receive the required pixel values from the correct positions. These pixel values are then used to determine the medians of the ‘x’ and ‘+’ neighborhoods respectively. These medians are in turn used to calculate the median along with the centre pixel of the image which in turn produces an output image.

The output can be seen in the following example ‘figure 4’:

![Figure 4 a. Original image b. Noisy image c. Filtered image](image)

5. **Objective analysis**

From the various results, an objective analysis can be made about how a hybrid median filter is more effective as compared to an arithmetic mean or regular median filter. Taking an example of the following images ‘figure 5’, a table (table 1) can be formulated in order to show the difference in SNR values of the original image, noisy image and the images filtered by mean and hybrid median filters:
Figure 5. Hubble image

Table 1. SNR values

| Image       | SNR value (dB) |
|-------------|----------------|
| Original    | 20.1408        |
| Noisy       | 13.4343        |
| Mean Filtered | 19.1523    |
| HMF Filtered | 19.8964     |

6. Conclusion

In conclusion, Hybrid Median Filters are more effective than conventional arithmetic mean filters and conventional median filters as it works on a three-ranking operation. It has the advantages of preserving corner details and also does not eliminate line details. A Hybrid Median Filter can be effectively used for removing noise from images. This makes it a viable option for practical applications such as image restoration, de-speckling in medical images, image enhancement etc.

Acknowledgments

I would like to acknowledge Dr. Jagdish Nayak and Dr. Abdul Rajak for mentoring, and guiding me with my work.

I would also like to thank Dr. R.N. Saha, for providing us with the opportunity to work on such a project through this institution.

References

[1] HarikiranB and Saichandana B D 2010 Impulse Noise Removal in Digital Images International Journal of Computer Applications pp 39-42

[2] Rakesh M R, Ajeya B and Mohan A R 2013 Hybrid Median Filter for Impulse Noise Removal of an Image in Image Restoration International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering pp 5117-5124

[3] Sailuddin D, Zainal H, Iza S, Fadzil A and Siti N 2020 Performance comparison of hybrid median filter with local preserving and conventional median filter for random-valued impulse noise removal International Journal of Advanced Science and Technology
[4] Daniel E A and Samuel A R 2017 A Genetic-Algorithm based Framework for Soft Handoff Optimization in Wireless Networks *Studies in Engineering and Technology* 5

[5] Gonzalez and Woods 2002 Digital Image Processing *Prentice Hall* 2

[6] W K Pratt 1975 Median Filtering *University of Southern California*