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Resilient EDGE Detection Method for Significant IMPULSE Noise

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ABSTRACT

The present study introduces a novel technique for detecting edges in images by means of the Switching Adaptive Median and Fixed Weighted Mean (SAMFWM) filter, which proves to be highly effective in removing impulse noise compared to conventional denoising filters that are currently available, while preserving edge details, thus ensuring optimal edge detection. The performance of the proposed approach is assessed using a comprehensive analysis of different performance metrics, including Mean Square Error (MSE), Structural Similarity Index (SSIM), and Peak Signal-to-Noise Ratio (PSNR). In addition, the Sobel operator is used to detect the edges and Non-Maximum Suppression is used to track and thin the edges. These techniques are utilized to handle edge discontinuities and detect edges in the presence of high-intensity noise. Furthermore, the proposed approach outperforms other alternative techniques such as the Robert, Prewitt, and Canny edge detectors in effectively removing impulse noise, even at high levels.

KEYWORDS:

Denoising, Edge Detection, Impulse noise, Non-Maximum Suppression, SAMFWM, Sobel operator.

1. INTRODUCTION

In the contemporary era, digital images are frequently employed to transmit visual data. However, during the transmission process, the received image can be corrupted by undesirable patterns or information referred to as noise. To recover the original content of the image prior to using it for any applications, linear or nonlinear filters must be applied through image processing. Edge detection is a fundamental task in image processing, used to identify the boundaries between different objects or regions within an image.

However, when images are corrupted by impulse noise, which is a type of noise characterized by sudden and abrupt changes in pixel intensity, the task of edge detection

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becomes more challenging. The noise filtering stage aims to remove the noise from the image, while preserving the edges as much as possible. The edge detection stage then identifies the edges present in the filtered image. Here noise removal is an important phase in edge detection because a good image gives better edges. Using traditional filters can cause various side effects such as blurring of image. Generally, all the edge detection algorithms perform better with noise less images. There are many different approaches to performing edge detection in the presence of impulse noise, and the choice of technique will depend on the specific characteristics of the noise and the image being analysed. Some commonly used methods include median filtering, adaptive filtering, and wavelet-based methods. Overall, edge detection in the presence of impulse noise is an important problem in image processing, and its solution can have significant applications in fields such as computer vision, medical imaging, and remote sensing.

The underlying motivation is based on two guiding principles: the first one is to address the obstacles encountered with denoising techniques while retaining maximum details, preventing image blurring, to preserve edges as much as possible and maintaining sharp boundaries. The second one is to tackle these hurdles, even in the presence of impulsive noise with high intensity.

2. LITERATURE SURVEY

Noise reduction is a crucial initial phase in detecting edges. Because it helps to remove noise and unwanted details from the image, which can interfere with the accurate detection of edges. The SAMFWM filter is a new type of filter that combines the features of median and mean filters. It has been demonstrated to produce superior structural metrics, which means it performs better than other filters in terms of accuracy. Therefore, using SAMFWMF can simplify and enhance edge detection[1]. The boundaries are detected but keeping image details under varying noise intensities was not the primary goal, despite successful edge detection [4]. The study offers a comparative evaluation of denoising filters, including the conventional median filter and others mentioned in 6, 7, 8 [5]. They all are extensions of the conventional mean and median filters and also, they give better results than mean and median filters. The results say that MDBUTMF is somewhat better. First step deals with mean and the second step deals with winsorized mean [8-9]. Usage of Sobel operator to find the edges[10]. It involves convolving the image with two 3x3 kernels that are used to compute the gradient of the intensities of the image. The various comparison metrics are used to check the level of similarity of filtered images [12]. The both [13] and [14] covers to obtain the edges from original images directly which cannot obtain if applied directly on noisy images and methods listed may obtain edge images directly from a noisy image without doing regularization.

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Canny edge detection algorithm can also be applied for noisy images [15]. Edge detection has several applications in real life. It is the basic step in many applications [16]. The various operators in edge detection and their applications are specified here. It specifies the License plate recognition [17]. The conventional Prewitt edge detection method is prone to noise interference, prompting the development of an enhanced Prewitt algorithm for more strong edge detection [18], which preserves better edges. The comparison among various popular edge detectors is provided in [19]. To evaluate the edge detection process, a comparative analysis was conducted using various methods including Canny edge detection, Prewitt operator, Robert operator, and Sobel operator [20] [21-29].

3. PROPOSED SYSTEM

The study presents a strong method for detecting edges that incorporates a denoising process for images with significant impulse noise. The method involves two phases. The first phase is denoising. The filtered image is checked for similarity with the traditional filter images, which are obtained by traditional mean and median filters using MSE, PSNR and SSIM. The second phase involves finding the edges in the filtered image. For this Sobel operator is used, but Sobel operator gives thick edges. To overcome this non maximum suppression is used to track the edges, edge discontinuities and edge thinning. The final result gives the edges of the filtered image. At last, the final resulting image is compared with other existing edge detection operators such as Robert operator, Prewitt operator and Canny edge detector.

3.1 Applications of proposed system:

Edge detection is a vital image processing technique used in object recognition, image enhancement, optical character recognition, and medical imaging. With the increasing importance of computer vision and image processing, the development of efficient edge detection algorithms has become crucial.

3.2 BLOCK DIAGRAM

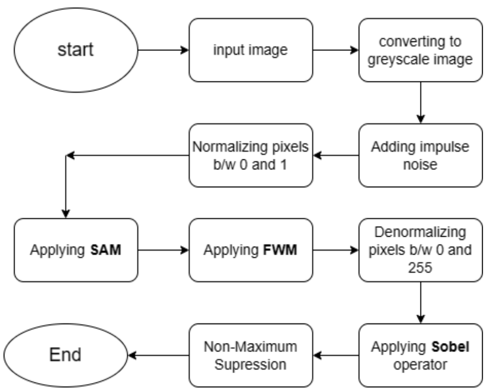

Fig 3.2.1: Block diagram of proposed method

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3.3 METHODOLOGY

3.3.1 DENOISING METHODS

A. SWITCHING ADAPTIVE MEDIAN

Switching Adaptive Median (SAM) filtering is a nonlinear image denoising technique designed to eliminate impulsive noise from digital images. In this model, the probability value for pixels corrupted with salt noise is denoted as P_s and pepper noise is denoted as P_p. After normalization 0 represents the minimum intensity value (I_{min}) and 1 represents the maximum intensity value (I_{max}). In this process, an initial 3x3 matrix is taken and convoluted on image. It is applied to every pixel and replaces it with the median of the window.

When the variance of the pixel values in an image is significantly greater than the median value, the window size is incremented by two, and the process is repeated until the maximum window size is reached. If the variance is significantly higher than the median value, an edge may be present. In this case, the median value can detect the edge, while in its absence, it can be correlated with the texture within the window. To prevent the final image from blurring, an adaptive extra window is used to remove any remaining noise in the black and white regions. This technique optimizes the results of the process.

Algorithm for SAM:

```
I  input image
r  no.of rows in image I
c no.ofcols in  image I
output = a 2d array of image size with all 0's
Win_min  Take window size 3x3
Win_max  Take window size 5x5
for i=1 to r
   for j=1 to c
      repeat until Win_min ≤ W ≤ Win_max do
S_min  Sort the values in W
            M Take median of S_min
            V  Variance of S_min
             if V ≤ 2*M then Break;
if V > 2*M then
        W  Win_max
        S_max  Sort values in W
        M  Median of S_max
outputImage = M
return I  outputImage
```

B. FIXED WEIGHTED MEAN

Fixed Weight Mean (FWM) filter is a type of image filtering technique used for noise reduction. The fixed weights are used to control the amount of smoothing applied to the image. SAM is applied on every pixel in the image, but FWM is applied over only corrupted

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pixels i.e., the pixels with 0 or 1 value. In FWM a 2x2 kernel is taken and convoluted over image pixels. if the current processing pixel I(i,j) in the window then (I(i, j), I(i, j+1), I(i+1, j), I(i+1, j+1)) are its neighbours. A pixel is corrupted if and only if I(i,j)=0 Or 1.If corrupted then the following operations are performed.

- If the window contains more 0's than 1's then the weight $w_{x,y}$ = 2 for the east and south pixels and $w_{x,y}$ = 1 for the southeast pixel.
- otherwise the weight is set to $w_{x,y}$ = 1 to all the neighbouring pixels in the window.

Algorithm for FWM:

```
I  input image
r  no.of rows in image I
c  no.ofcols in image I
currWin  Current Window
no.of1s  count of 1's in currWin
no.of0s  count of 0's in currWin
for i=1 to r
   for j=1 to c
      if I(i,j)==0 or 1
         mean  take mean of currWin
         Wmean  weighted mean of currWin
         for i1 in currWin rows
            for j1 in currWin cols
               if (i1,j1)==1
                  no.of1s  no.of1s+1
               else no.of0s  no.of0s+1
         if no.of1s > no.of0s I(i,j)  mean
         else     I(i,j)  Wmean
else     I(i,j) I(i,j)      return I.
```

3.3.2 EDGE DETECTION METHODS

A. SOBEL OPERATOR

Removing noise is a key step in edge detection, because a good image leads to good edges. So, after removal of noise from the image using SAMFWM filter, In this method, the detection of edges is achieved through the application of the Sobel operator, which calculates the gradient values in both the vertical and horizontal directions. The Sobel operator performs convolution by using two 3x3 kernels to calculate the intensity gradient of the image, allowing the detection of edges with varying angles and orientations. The Sobel gradient is a weighted sum of the pixel values in the neighbourhood of the pixel being processed. Specifically, each pixel in the kernel is multiplied by its corresponding weight and the resulting values are then added together to obtain the gradient. This process is repeated for all pixels in the image, producing an output image that highlights the edges of the image.

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-1	0	1
-2	0	2
-1	0	1

X-direction

-1	-2	1
0	0	0
1	2	1

Y-direction

fig 3.3.2.A.1: Horizontal & Vertical Kernels

$$G_r(f(i, j)) = (f(i-1, j-1)) + 2(f(i-1, j)) + (f(i-1, j+1)) - (f(i+1, j-1)) - 2(f(i+1, j)) - (f(i+1, j+1))$$

$$G_c(f(i, j)) = (- f(i-1, j-1) - 2(f(i, j-1)) - f(i+1, j-1)) + (f(i-1, j+1) + 2(f(i ,j+1) + (f(i+1, j+1))$$

fig 3.3.2.A.2: Horizontal & Vertical Gradient values

Where, G_r, G_c gradient over rows and columns

Overall Gradient Magnitude is $G = \sqrt{(G_r^2 + G_c^2)}$

Algorithm for Sobel Operator:

```
function [t]=Sobel(image)
filtered_image = zeros(size(image));
Mx = [-1 0 1; -2 0 2; -1 0 1];
My = [-1 -2 -1; 0 0 0; 1 2 1];
for i = 1:size(image, 1) - 2
for j = 1:size(image, 2) - 2
        Gx = sum (horizontal gradient)
        Gy = sum (vertical gradient)
        filtered_image (i+1, j+1) = sqrt(Gx^2 + Gy^2)
thresholdValue = 100;
oim = max (filtered_image, thresholdValue)
oim (oim == round(thresholdValue)) = 0
return oim
```

B. NON-MAXIMUM SUPPRESSION

Non Maximum Suppression is a post-processing technique used image processing to identify the local maxima in an image. It is typically used after edge detection to eliminate false edge detections and to thin the edges to one-pixel width. It works by comparing the edge strengths at each pixel location and suppressing all non-maximum values in each neighbourhood. This process ensures that only the strongest edges are retained, which reduces the number of false positives.Initially, it computes horizontal and vertical gradients as given below:

$$G_r(f(i, j)) = (f(i-1, j-1)) + 2(f(i-1, j)) + (f(i-1, j+1)) - (f(i+1, j-1)) - 2(f(i+1, j)) - (f(i+1, j+1))$$

$$G_c(f(i,j)) = (- f(i-1, j-1) - 2(f(i, j-1)) - f(i+1, j-1)) + (f(i-1, j+1) + 2(f(i ,j+1) + (f(i+1, j+1))$$

fig 3.3.2.B.1: Horizontal & Vertical Gradient values

Then the angle of gradient is calculated as shown:

$$\text{Angle} = \tan^{-1}(G_r / G_c) \text{ ------->eq1}$$

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Algorithm for Non-Maximum Suppression:

Function outputImg = nonMaxSuppression(sobelImg)
[rows, cols] = size(sobelImg)
outputImg = zeros(rows, cols)
[G_x, G_y] = imgradientxy (sobelImg, 'Sobel')
[G_{mag}, G_{dir}] = imgradient (G_x, G_y)
G_{dir} = round (G_{dir} / 45) * 45
for i = 2 to rows - 1 do
    for j = 2 to cols - 1 do
        switch G_{dir}(i, j)
          case 0:
              if (G_{mag}(i, j) >G_{mag}(i, j-1)) and (G_{mag} (i, j) >GG_{mag}(i, j+1))
outputImg (i, j) = G_{mag} (i, j)
           case 45:
              if (G_{mag} (i, j) >G_{mag}(i-1, j+1)) and (G_{mag}(i, j) >G_{mag}(i+1, j-1))
outputImg (i, j) = G_{mag} (i, j)
           case 90:
              if (G_{mag}(i, j) >G_{mag}(i-1, j)) and (G_{mag}(i, j) >G_{mag}(i+1, j))
outputImg (i, j) = G_{mag} (i, j)
           case 135:
              if (G_{mag} (i, j) >G_{mag}(i-1, j-1)) and (G_{mag}(i, j) >G_{mag}(i+1, j+1))
outputImg (i, j) = G_{mag} (i, j)
    return outputImg

4. RESULTS AND CONCLUSION

4.1 EXPERIMENT SET:

		
(a) Lena	**(b) Camera Man**	**(c) Coins**
		
(d) Flower	**(e) Apple**	**(f) Dog**

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(g) Rose	(h) Bird	(i) Leaves

fig 4.1.1: Set of Images

The Experiment Set consists of 9 images which were used for denoising and edge detection. Three performance metric measures are used to compare the proposed method and various techniques, they are

1. MSE (Mean Square Error)
2. SSIM (Structural Similarity Index)
3. PSNR (Peak Signal-To-Noise Ratio)

1.Mean Square Error (MSE)

$$MSE = \frac{1}{mn}\sum_{0}^{m-1}\sum_{0}^{n-1}\|f(i,j) - g(i,j)\|^2$$

------>eq2

It calculates the mean variation between the pixels of the image. Where, f, g are pixel data of original and filtered images and m,n shows rows and columns

2.Structural Similarity Index (SSIM)

A measure to evaluate the visual perception of an image based on its luminance, contrast, and structure is referred to as an image quality metric

$$SSIM(x,y) = [l(x,y)]^{\alpha} \cdot [c(x,y)]^{\beta} \cdot [s(x,y)]^{\gamma}$$

------>eq3

Where, l is a function that compares brightness(luminance), c is function for difference of brightness and color, s is Function for assessing the similarity of the structural features

3.Peak Signal-to-Noise Ratio (PSNR)

PSNR is a metric that evaluates image quality by measuring the ratio of the maximum pixel value to the distortion of an image caused by noise or other factors.

$$PSNR = 20\log_{10}\left(\frac{MAX_f}{\sqrt{MSE}}\right)$$

------>eq4

MAXf is the image's maximum pixel value

4.2 RESULTS:

In order to evaluate the effectiveness of a proposed method for image processing, it is essential to conduct both subjective and objective assessments. Subjective assessment

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involves the use of human observers to evaluate the quality of images, which can be done through an absolute rating scale or a side-by-side comparison.

Objective assessment can be performed using various metrics such as PSNR, MSE, and SSIM. These metrics provide quantitative measurements of image quality, with higher values indicating better quality. Therefore, a proposed method can be considered effective if it achieves higher values in these metrics compared to existing methods.

4.2.1 SUBJECTIVE ANALYSIS:

A. Denoising filters comparison:

According to the results shown in Figure 4.2.1.A.1, Images processed with the SAMFWM filter exhibit superior qualities, such as heightened luminosity and sharper details, while also showcasing a reduction in noise levels when compared to the Median and Mean filters. The conventional Median and Mean filters are inclined to smoothen the image, causing a reduction in image details. Conversely, the proposed technique preserves image details and enhances the overall visual quality of the image.

The proposed approach successfully achieved noise reduction without compromising the image's details.

Fig 4.2.1.A.1: Lena-impulse noise image, Median Filter, SAMFWM filter

Fig 4.2.1.A.2: Cameraman-impulse noise image, Median, SAMFWM filter

Fig 4.2.1.A.3: Flower-impulse noise image, Median Filter, SAMFWM filter

B. Edge detection comparison:

The figures mentioned in the section4.2.1.B, demonstrates the edge detection outcomes of various techniques (Proposed, Sobel, Prewitt, Robert and Canny) on multiple images, each having 10% impulse noise. In comparison to other methods, the proposed method outperformed in extracting edges precisely throughout the entire image. The results also demonstrated the proposed method's proficiency in identifying edges in images corrupted

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with impulse noise. Comparisons state that the Sobel operator performs better than other operators on filtered images.

Fig 4.2.1.B.1: Sobel Edge Detection

Fig 4.2.1.B.2: Prewitt Edge Detection

Fig 4.2.1.B.3: Robert Edge Detection

Fig 4.2.1.B.4: Canny Edge Detection

Fig 4.2.1.B.5: Proposed Edge Detection

4.2.2 OBJECTIVE ANALYSIS:

The purpose of the assessment is to compare and evaluate the efficiency of different image denoising methods and edge detectors.

Table I, II, and III illustrate the results obtained by implementing SAMFWM, median filter, and mean filter on diverse images.

The evaluation metrics used for the comparison are mean square error (MSE), structural similarity index (SSIM), and peak signal-to-noise ratio (PSNR), where higher PSNR and SSIM values and lower MSE values indicate better image quality. These results show the proposed method (SAMFWM) works well and yields better results than others.

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Table I: PSNR, MSE, SSIM results of Lena for Median, Mean SAMFWM

	Lena (Median)	**Lena** (Mean)	**Lena** (SAMFWM)
PSNR	-23.105	-23.410	-22.345
MSE	170.60	169.50	158.08
SSIM	0.6134	0.5989	0.7212

Table II: PSNR, MSE, SSIM results of Flower for Median, Mean, SAMFWM

	Flower (Median)	**Flower** (Mean)	**Flower** (SAMFWM)
PSNR	-22.635	-22.90	-22.012
MSE	232.76	236.68	210.99
SSIM	0.6812	0.6679	0.7798

Table III: PSNR, MSE, SSIM results of Flower for Median, Mean, SAMFWM

	Dog (Median)	**Dog** (Mean)	**Dog** (SAMFWM)
PSNR	-17.012	-17.14	-16.524
MSE	33.2564	33.787	32.9816
SSIM	0.9348	0.9723	0.9338

4.3 CONCLUSION:

A novel image quality enhancement technique, termed SAMFWM filtering, has been proposed as a solution to reduce noise levels in images, and has been demonstrated to be highly effective, particularly under conditions of high-intensity impulse noise. To gauge the efficacy of the proposed and other denoising techniques, standard measures like PSNR, SSIM, and MSE are employed to evaluate edge preservation and image structure. The proposed algorithm is found to be superior to existing methods as it considers multiple neighbouring pixels across various scales, leading to better edge detection and higher image quality. Results from experiments show that the proposed method is capable of accurately

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identifying edge pixels, even under high-intensity impulse noise conditions, resulting in significantly better image quality.

5. LIMITATIONS AND FUTURE SCOPE

Edge detection algorithms can be limited in their ability to detect edges that are not continuous or that have gaps. The proposed algorithms can only handle impulse noise, this cannot handle other noises. Researchers could investigate hybrid approaches i.e., combination of traditional and deep learning models. The proposed solution could be extended to video processing applications.

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