Sobel-Canny Fusion for Effective Edge Detection in Gaussian Denoised Digital Images

Sahana R[1,2], Manjula Gururaj Rao[3] and Ganesh Aithal[2]
[1]*Dept. of CSE, NTTTE (Deemed to be University), NMAMIT, Nitte, Karkala, India*
[2]*Dept. of CSE, SMVITM, Bantakal, India*
[3]*NTTTE (Deemed to be University), NMAMIT, Nitte, Karkala, India*

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Abstract: Information is essential in the digital age. These data may take the shape of pictures or statistics. Getting high-quality photos is crucial when working with image data. Unwanted information in an image is referred to as noise, and it presents a major difficulty for image analysis. Depending on the image format, many types of noise may exist. Image noise removal is a difficult process. The suggested effort focusses on removing noise from colored images, especially from video frames. To improve the quality of the frames by lowering noise, the model uses Non-Local Means Denoising, Gaussian Filter, and Bilateral Filter approaches. Time performance and PSNR (peak signal-to-noise ratio) measurements are used to assess how effective the techniques are. The final photos had substantially higher PSNR values. One important component of digital image/video processing is edge detection. Edge detection is essential for applications that required to extract features or object information from a picture. Although there are several different edge detection operators are available today, improving the performance of current system remains a difficulty In this study, the Sobel and Canny edge detectors are combined in a hybrid technique.

1 INTRODUCTION

Digital video is used in many applications like medical, entertainment, information technology, multimedia services etc. Both TV shows and movies have switched to digital and high definition, moreover now the majority of movies and certain TV shows are in 3D format. Digital video unites the movies, communication sector and computer, making phone, cable TV and internet providers bitter rivals. One device can function as phone, HD TV and personal computer. These days we can use mobile to record live video, a laptop to handle digital data and printer to produce still image.

Enhancing the image quality is an ongoing area of research. As low-end gadgets like mobile phones and webcams proliferate, digital image and video enhancements methods are increasingly needed to improve their outputs. The main cause of image quality degradation is noise. Thus, it is essential to explore denoising algorithm to generate high quality images and video frames. (Z. Liu,2014), (M. Maggioni,2012), (Mildenhall,2018) This paper focuses on video denoising. Here the objective is to develop high quality video denoising algorithm, that successfully eliminate noise introduced by digital cameras.

Low light, sensor flaws and thermal impacts are the causes of noise in the images. It requires lot of time and effort to manually adjust several parameters in order to enhance the quality and bandwidth of cameras. In real world scenario, where color and light conditions may vary abruptly creating a distinct noise distribution for every frame, it is required to have noise reduction algorithm that operates on blind settings. The majority of conventional denoising techniques choose and average the images pixels to provide good results. The fundamental components of various denoising techniques are how to efficiently choose appropriate pixels and calculate the averaging weights. Filters can be used to improve and reduce the noise in images and video frames. (Antoni Buades, 2011) A linear filter type based on gaussian function is called gaussian filter. The bilateral filter is however non-

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linear filter type. It eliminates the noise while maintaining the edge. Edge detection is essential for applications that required to extract features or object information from a picture. Although there are several different edge detection operators are available today, improving the performance of current system remains a difficulty. In this study, the Sobel and Canny edge detectors are combined in a hybrid technique.

The section 2 focuses on the work done in the removal of the noise from the images and proposed work, implementation and the results are discussed in the sections 3, 4 and 5 respectively

2 RELATED WORK

Denoising and edge detection of images and videos has been researched for many years. Since providing a comprehensive analysis is beyond the scope of this paper, we will concentrate on examining the work that is most relevant to ours.

Recently concept of image sparsity has been introduced as image self-similarity, meaning that patches within image exhibit similarities to each other, which give rise to non-local methods (Buades,2005). In NLM similar patches combined with the weights that reflect with their similarities. This straight forward approach yields high quality outcomes. NLM techniques tests the images with different noise levels. According to experimental data this algorithm enhances the denoising performances (Lingli Huang,2015). For this reason, we have selected NLM as the one of the methods in our denoising system.

One of the linear filters called gaussian filter used to smooth and remove the noise from images(M. G. Rao H,2019). Test and evaluation report indicates that, it can be applied to enhance the image quality (Sriani,2022) (Kumar,2020). The gaussian filter approach is particularly useful for filtering images with lot of noise, since filtering finding shown a robust dependence on gaussian kernel and relative independence on noise features (Priyanka, 2020).

A nonlinear technique for denoising images while maintaining the sharp edges is bilateral filtering. The weighted sum of each pixels neighbors in the input image determines its value in the output image (P. D. Patil, 2015). It performs better than linear filter like mean filter, weiner filter. In high frequency area it performs better at eliminating the noise, while in low frequency area it is ineffective (Bhonsle,2012).

One important component of digital image/video processing is edge detection. The performance of each edge detection techniques is examined through comparison. The findings demonstrated that in contrast to Roberts and Prewitt operators, Sobel and Canny edge detectors are less sensitive to random noise in an image (Amer,2015) It is also suggested to combine the canny and sobel operator for edge detection (A. Kalra,2016).

In the proposed work focuses on the removal of the noise using non local means denoising, Gaussian filter and bilateral filtering. These algorithms are compared and assessed using two kinds of metrics. The PSNR and time performance are used as evaluation metrics to determine the optimal filter to reduce noise from frame under various conditions.

The Gaussian filter has been proven to be superior in both the situations, however it does not retain the edges for subsequent processing. To get around this, hybrid approaches have been developed to identify the edges in images while using the Gaussian noise removal methods.

3 PROPOSED WORK

Three different methods have been implemented to carry out denoising.

1. Non-Local Means Denoising
2. Gaussian Filter
3. Bilateral Filter

These methods perform denoising on each frame and writes the denoised frames to an output video

3.1 Non-Local Means Denoising

The fundamental principle of Non local means denoising is to substitute the average color of neighboring pixels for pixel's original color. In probability theory, the variance law guarantees that the noise standard deviation of an average of nine pixels is divided by three. Therefore, one can split the noise by three (and four with sixteen identical pixels so on), if we can locate nine other pixels in the image that are the same color as each pixel. To identify all the pixels that actually resemble the pixel needing denoising, it is acceptable to scan a large area of the image. After that, denoising is accomplished by calculating the average color of these pixels that are most similar. Instead of focusing only on color, the likeliness is assessed by

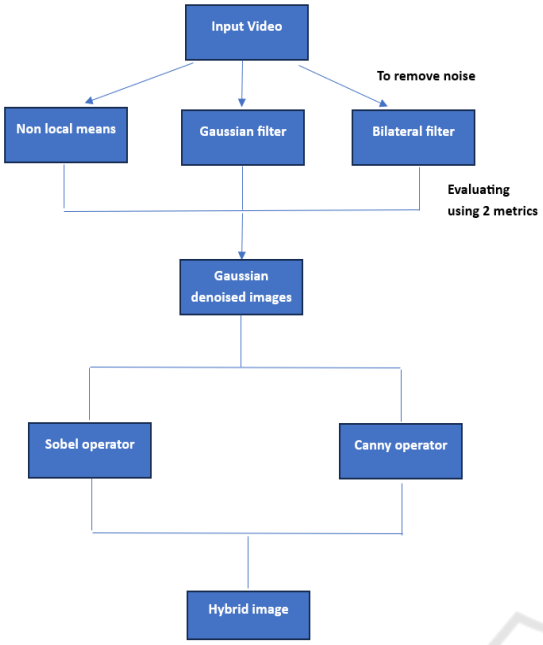

Figure 1: Proposed Algorithm.

analyzing the entire window surrounding each pixel. We refer to this filter as non-local means (Buades,2006) (Buades,2005) and it is given by equation (1).

$$NLu(p) = \frac{1}{C(p)} \int f(d(B(p), B(q))u(q)dq \quad (1)$$

The Euclidean distance between image centered between p and q respectively is represented as d(B(p), B(q)), f is a decreasing function, C(p) is the normalizing factor.

3.2 Gaussian Filter

The most common form of noise in digital image or video is Gaussian noise, while there are other varieties as well such as impulse noise, speckle noise and pepper noise. The gaussian noise in image/video arises from sensor constraints' during low light conditions, which hinder the light sensor's ability to effectively record scene details. The bivariate circular Gaussian function equation (2) can be used mathematically to describe gaussian noise as follows

$$g(x, y) = \frac{1}{2\pi\sigma_x\sigma_y} e^{-\frac{-[(x-\mu_x)^2+(y-\mu_y)^2]}{(2\sigma_x\sigma_y)}} \quad (2)$$

Where σ_x, σ_y are standard deviations and μ_x, μ_y are the means.

In general, the output of the gaussian filter, which uses the weighting function with a gaussian distribution, is an average of the pixel values within a specific neighborhood. This method involves reducing the lot of high frequency noise such as edges and small features to produce a smoother image. The degree of smoothing function is determined by Gaussian function standard deviation or sigma

- Small sigma: They preserve more of the surfaces and objects characteristics and details since they have less smoothing
- Large sigma: A bit more smoothing, even capable of erasing the key characteristics

Figure 2 depicts the relationship between function value and standard deviation. Additionally the function's maximum value decreases as standard deviation increases, other values deviating from mean also increases (Gonzalez, 2007).

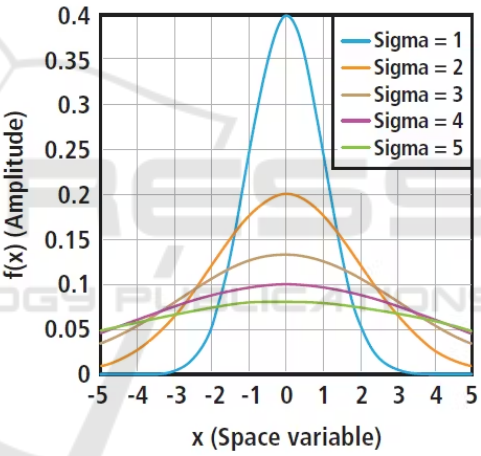

Figure 2: The graph shows variation in function value according to the sigma value

3.3 Bilateral Filter

Bilateral filter is defined as weighted average of adjacent pixels, much like gaussian filter. The bilateral filter differs in that it preserves the edges during smoothing by considering the difference in value with neighbors. The fundamental principle of this filter is that a pixel must have a similar value in addition to occupying a nearby location, in order to affect another pixel. The bilateral filter denoted by BF[] is given by equation (3)

$$BF[I]_p = \frac{1}{W_p} \sum_{q \varepsilon S} G_{\sigma_s}(||p - q||) G_{\sigma_r}(|I_p - I_q|) I_q \quad (3)$$

Where normalization factor W_p guarantees pixel weights sum to 1.0

$$W_p = \sum_{q \varepsilon S} G_{\sigma_s}(||p-q||) G_{\sigma_r}(|I_p - I_q|) \quad (4)$$

The amount of filtering applied to the picture is determined by σ_s *and* σ_r. G_{σ_s} is a spatial gaussian weighting and G_{σ_r} is a range gaussian.

Two parameters σ_s *and* σ_r controls the bilateral filter

- As the parameter σ_r increases, the bilateral filter progressively approaches gaussian filter more closely because G_{σ_r} flattens and widens
- Larger features are smoothed by increasing parameter σ_s

For comparing between the above three algorithms, we used two evaluation metrics.

i. The first metric is time. The time taken by the whole program is calculated

ii. The second metric is PSNR. A standard metric for assessing the quality of any video or image is PSNR. In general, higher PSNR denotes the higher quality reconstruction. The formula given in below equation (5) is used to determine the videos PSNR

$$PSNR = 20 \log_{10} MAX_I - 10 \log_{10} MSE \quad (5)$$

MSE is mean squared error which is calculated using below formula

$$MSE = \frac{1}{mn} \sum_{i=0}^{m-1} \sum_{j=0}^{n-1} [I(i,j) - K(i,j)]^2 \quad (6)$$

Where I is the original Image, K is the denoised image, MAX_I is the maximum possible pixel value

It has been discovered that in both case Gaussian filter outperform compared to other two algorithms. Gaussian filter on the other hand do not maintain the edge when eliminating noise. Gaussian denoising is not ideal for further image or video processing as it does not effectively preserve the edges. Hybrid approaches have been put forth to improve edge identification in gaussian denoised frame in order to overcome this constraint. Specifically, combination of Sobel and canny edge detection algorithms is employed to accurately identify the edges while mitigating the effects of gaussian noise.

One important component of digital image/video processing is edge detection. Edge detection is essential for applications that required to extract features or object information from a picture. Edge happens when the intensity functions abruptly change or becomes discontinuous. Although there are several different edge detection operators are available today, improving the performance of current system remains a difficulty. In this study, the Sobel and Canny edge detector are combined in a hybrid technique. Additionally, gaussian filter eliminates noise from images and video when edge identification is challenging by using it.

3.4 Sobel Edge Detector

The first order differential is the foundation of the Sobel operator. This operation applies small, separable integer valued filter to the image in both x and y directions, making it computationally inexpensive. It functions as an orthogonal gradient operator, calculating the partial derivatives in both x and y directions using 3x3 neighborhood of f(x,y) (Moslem, 2011). The gradient in oblique direction is given by equation (8)

$$g(x,y) = |S_x| + |S_y| \quad (7)$$

$$where\ S_x = \{f(x+1,y-1) + 2f(x+1,y) + f(x+1,y+1)\} - \{f(x-1,y-1) + 2f(x-1,y) + f(x+1,y-1) \quad (8)$$

$$and\ S_y = \{f(x-1,y+1) + 2f(x,y+1) + f(x+1,y+1)\} - \{f(x-1,y-1) + 2f(x,y-1) + f(x-1,y+1) \quad (9)$$

Sobel edge detection has 2 benefits.

i) It smooths out some of the undesired noise in a picture.

ii) By using differential of two rows and two columns, edge's element are strengthened, making it thicker and brighter

3.5 Canny Edge Detector

A multi stage technique for identifying the different edges in images or videos is called as canny edge detector. Due its excellence performance, it is sometimes referred as ideal edge detector. The core concept of canny operator is to get the derivatives of the first order of a gaussian function in any direction to serve as a noise filter(Cai-Xia Deng, 2013). This filter can be used to find the greatest value of the

local gradient. As a result, image edge can be identified.

3.6 Proposed Algorithm

The accuracy of edge detection and efficient noise reduction is the focus of this research. A gaussian filter, which effectively removes noise has been implemented for effective noise removal. The benefits of each technique are combined in this hybrid algorithm. The suggested approach as shown in Figure 1 seeks to address the drawback of both denoised gaussian image and the current edge detection methods, Sobel and canny.

Step 1: Take any video as input, and if necessary, add noise to it.
Step 2: To eliminate the noise from the video, apply bilateral, gaussian and non-local filters.
Step 3: Use the PSNR and time as the two evaluation measures to determine which method performs the best.
Step 4: Apply the sober edge detector first to the image and record the result as SE
Step 5: Next use the canny edge detector to examine image and save the result as CE
Step 6: Create a hybrid of two outcomes as in equation (10)

$$Hybridimage = SE + CE \qquad (10)$$

4 RESULTS AND DISCUSSIONS

Three approaches have been utilized for denoising, non local means denoising, gaussian filter and bilateral filter. Videos of varying length have been used as input for these algorithms. The original image and outcome of the non-local means denoising is compared in Figure 3(a), Figure 3(b) contrasts the original image with gaussian filter, Figure 3(c) compares the original image with bilateral filter.

These algorithms have been evaluated using two metrics: execution time and PSNR. We analyzed videos of various lengths and execution time of all three methods were recorded as shown in Table 1. The bar graph in Fig 4 illustrates the same. Results indicates that the Gaussian filter consistently outperforms the other two algorithms across all

(a) Original Image Vs Non Local Means denoising

(b) Original Image Vs Gaussian Filter

(c) Original Image Vs Bilateral Filter

Figure 3: Output of three different algorithms

videos. Additionally, it was observed that for videos longer than two hours, non-local means denoising requires over 24hrs to complete

Table 1: Comparison of three methods using execution time

Video Duration(min)	Non Local Means(sec)	Gaussian Filter(sec)	Bilateral Filter(sec)
0.2	268	4	24
5	13602	137	573
10	23532	306	924
25	54765	639	6374
60	83589	1649	13668
142	167896	2849	22471

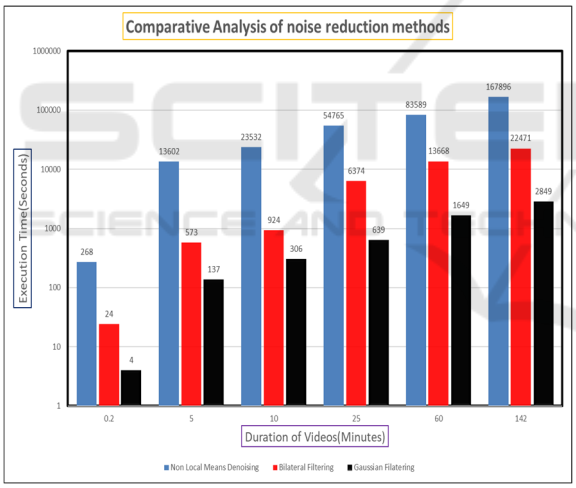

Figure 4: Comparative analysis of noise reduction methods using Execution Time

In a similar manner, we have assessed the three approaches using PSNR metrics, which evaluate the video quality. Videos of various lengths were analyzed and PSNR values for each of the three methods are shown in Table2. The bar graph in Fig. 5 reflects the same information. It was observed that using second metric PSNR, Gaussian filter surpasses the other two techniques.

Table 2: Comparison of three methods using PSNR

Video Duration(min)	Non Local Means(dB)	Gaussian Filter(dB)	Bilateral Filter(dB)
5sec	30.15	31.22	30.85
10sec	30.07	31.49	30.31
30sec	31.44	33.31	32.28
1min	29.04	31.45	30.29
5min	28.11	29.44	28.67
10min	31.02	32.33	31.13
30min	29.65	30.19	29.89
45min	32.25	33.27	32.81
1 hour	29.32	31.69	29.81

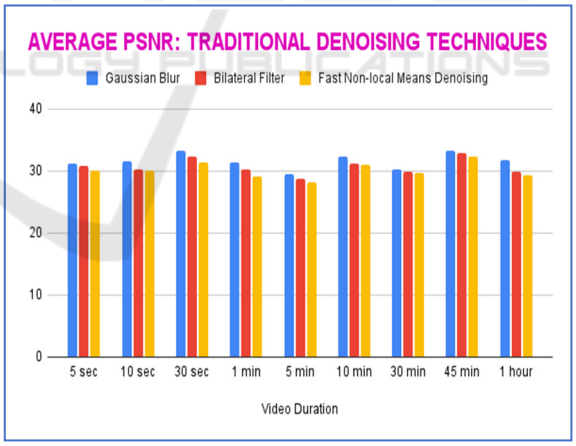

Figure 5: Comparative analysis of noise reduction methods using PSNR

The original image is displayed in Fig. 6(a). This image is smoothed and the noise id removed when gaussian filter in applied. After filtering smoothed image is displayed in Fig. 6 (b). Edge detection is more successful after filtering. The image after applying the Sobel operator is displayed in Fig. 6(c). It is evident that certain elements have been masked by the image's edges. The outcome of applying the

canny operator is displayed in Fig. 6(d). As the canny operator exhibits the lower sensitivity to noise than Sobel operator, it is evident that the edges are clearer. However, some edges are taken up by the Sobel operator rather than canny operator. In this situation, hybrid strategy aids in producing the effective outcomes. The algorithm's final output is depicted in Fig. 6(e). It incorporates the benefits of the three elements.

Figure 6: Original Image and gaussian denoised image

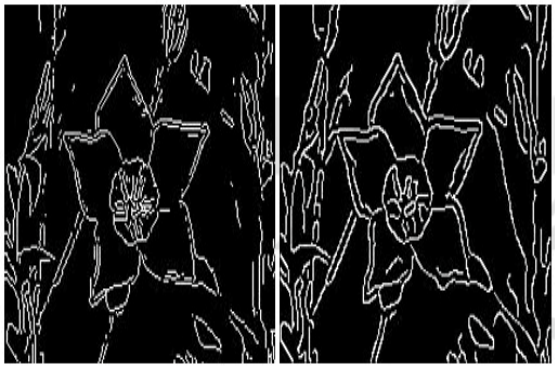

Figure 7: Sobel edge detection and Canny edge detection

Figure 8: Proposed algorithms Hybrid image

5 CONCLUSION AND FUTURE WORK

An essential stage in object extraction is edge detection. An image uses less storage space when edge detection is used. Edge detection is frequently used for image segmentation since it can identify objects and boundaries. Additionally edge detection aids in identifying the patterns in an image by extracting the key features. Hence it is essential to obtain high quality outcomes from edge detection methods. Individual operators cannot detect every edge on their own, this paper proposed a hybrid technique that leverages the benefits of both Sobel and Canny Edge detection algorithms. Additionally, the proposed algorithm incorporates a gaussian filtering to eliminate any noise and to enhance edge detection accuracy. The input image is smoothed using this gaussian filtering. Additionally, this gaussian filtering outperforms the other two techniques. The suggested algorithm achieves a very good edge detection effect and successfully increases edge detection accuracy.

Various deep learning technique can be used to perform this operation. The proposed algorithm is suitable for short videos. However, as the video duration increases, processing becomes significantly time consuming. To address this, parallel processing techniques can be utilized by distributing the workload across multiple threads, thereby enhancing the efficiency.

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