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High Performance Filter For Removing Impulse Noise From Video

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Abstract

Most of the video processing engines use all pixels within a window to filter out the impulse noise. These techniques remove edges and fine details present in the image and in several applications, this is not desirable. In the paper, an impulse noise removal scheme that emphasizes on few noise-free pixels is proposed. The noisy-pixel is replaced with the median value of the noise-free pixels. The iterative process continues until all noisy-pixels of the corrupted image are filtered. This scheme is proved to provide superior performance with negligible effects on edges as compared to the existing approaches, especially for high density salt-and-pepper noise. The quantitative results as well as the perceptual quality results are presented to validate our claim.

Keywords: Salt-and-pepper Noise, noise- free pixels, Iterative filtering, Non-linear filtering

Introduction

The term video ("video" meaning "I see", from the Latin verb "videre") commonly refers to several storage formats for moving pictures. It is the technology of electronically capturing, recording, processing, storing, transmitting, and reconstructing a sequence of still images representing scenes in motion. These images can be having just black and white colour or can have other colours in them. Digital images are often corrupted with the impulse noise during acquisition or transmission. The restoration of noise free images is carried out as a pre-processing task in a wide range of image applications.

Images taken with both digital cameras and conventional film cameras will pick up noise from a variety of sources. Noises such as digital noises (Salt and Pepper noise) and Gaussian noise are common in videos. In salt and pepper noise (sparse light and dark disturbances), pixels in the image are very different in colour or intensity from their surrounding pixels; the defining characteristic is that the value of a noisy pixel bears no relation to the colour of surrounding pixels. Generally this type of noise will only affect a small number of image pixels. When viewed, the image contains dark and white dots, hence the term salt and pepper noise. Typical sources include flecks of dust inside the camera and overheated or faulty CCD elements.

The noises at different pixels can be either correlated or uncorrelated; in many cases, noise values at different pixels are modelled as being independent and identically distributed and hence uncorrelated. The noisy-pixels contaminated with salt-and-pepper noise have two values – the minimum I min and maximum I max value within the dynamic range [I min, I max]. However, noisy pixels of image, corrupted with random-valued noise, have many random value from the dynamic range [I min, I max]. With the increase of noise density, in the image, numbers of noisy pixels are increased.

In traditional still and motion-picture photography, this restoration is done by using filters. During older days, a filter was a specialized piece of glass affixed to the lens to alter (and hopefully improve) the image. Today, the term "filter" more often refers to a small program or subroutine running inside an editing application. But, just like optical filters, electronic filters help you manage the look of your footage.

Commonly Used Filters

One method to remove noise is by convolving the original image with a mask that represents a low-pass filter or smoothing operation. This convolution brings the value of each pixel into closer harmony with the values of its neighbours. In general, a smoothing filter sets each pixel to the average value, or a weighted average, of itself and its nearby neighbours; the Gaussian filter is just one possible set of weights. Smoothing filters tend to blur an image, because pixel intensity values that are significantly higher or lower than the surrounding neighbourhood would "smear" across the area. Because of this blurring, linear filters are seldom used in practice for noise reduction; they are, however, often used as the basis for nonlinear noise reduction filters.

Another method for removing noise is to evolve the image under a smoothing partial differential equation similar to the heat equation which is called anisotropic diffusion. With a spatially constant diffusion coefficient, this is equivalent to the heat equation or linear Gaussian filtering, but with a diffusion coefficient designed to detect edges, the noise can be removed without blurring the edges of the image.

A median filter is an example of a non- linear filter and, if properly designed, is very good at preserving image detail. In this filter the original value of the pixel is replaced with the median value from the list. If the numbers of noisy pixels are greater than noise-free pixels then noise filtering become crucial. To filter out low density of salt-and-pepper noise is relatively simple. For this purpose, the simple linear filtering techniques are effective. However, due to the non-linear nature of impulse noise, linear techniques are unable to suppress properly the high density of salt- and-pepper noise.

Video processing engines commonly use the Standard Median Filter (SMF) and its variants for impulse noise filtering. The SMF based techniques replace every image pixel with the median value computed within the window without considering the status of(noisy/ noise-free) pixels. Consequently, the image fine details and the edges are lost. To enhance the capability of non- linear filters, the switching concept was introduced. The noisy-pixels detection is the first step in switching concept based techniques. The noisy pixels are detected using a criterion based on similarity or difference to the central pixel within neighbourhood. Absolute difference of the median or mean of the neighbouring pixels is one the simplest detection criterion. If this difference is greater than a certain threshold value then the central pixel is declared to be corrupted with noise. In a comprehensive comparative analysis of detection algorithm, once detection is performed, noisy pixels are filtered in second stage.

Among the variety of switching based filtering techniques, Adaptive Median Filter (AMF) has gained the most popularity. The AMF becomes computationally expensive for high noise density. To minimize this effect Progressive Switching Median Filter (PSMF), Decision Based Algorithm (DBA), and New Impulse Detection and Filtering (NIDF) algorithm have been developed. Mostly, these techniques estimate noisy pixels taking into account all pixels within the neighbourhood. In case of high noise density, these approaches extend the window size that consequently increases the number of noisy pixels. Due to these noisy pixels, the estimate from a larger window may not be accurate. A side effect of the larger window is more likely to remove edges and fine details, which ultimately degrades the quality of the filtered image.

Noise Free Iterative Filtering

Desideratum

Commonly used filtering techniques make use of the entire pixels in an image for filtering. This causes mainly three problems:

1. The computational complexity of the process is high making it less preferable for real-time-multi-frame processing
2. The filtering may introduce noise. For example, consider a 3x3 window based median filtering of an 8 BPP image. If the pixel values overlapped by the window are 255, 255, 87, 56, 255, 255, 19, 255, 54 where the pixel value 255 is contributed by the presence of snow noise and 54 corresponds to the central pixel. Now, on performing the median filtering, the pixel value ofthe central pixel is replaced with 255. That is, instead of removing noise, noise is introduced by the filtering operation.
3. The filtering operations remove information from the image; i.e., the process removes not only the noise but also the noise free pixel. For instance, if mean filtering is performed, the effect is similar to averaging. We know that the average of two distinct numbers will be greater than the lowest and lesser than the highest. Therefore, mean filtering smoothens the edges present in an image.

All the above mentioned difficulties are critical in case of noise reduction in digital images since the most vital information is contained in the edges, which will get smoothened out by filter. Therefore the desideratum is that the filtering process should remove noise with maximum efficiency without smoothening or blurring the edges of the image.

Concept

In the proposed iterative noise-free pixel mean filtering, an algorithm is employed so that the code initially segregates noisy and noise-free pixels. Once the pixels are segregated, the filtering process is done with the noisy pixels as the center element and noise-free pixels as the window elements. Thus, the noise present in the image is completely removed. The new pixel values and the values of the noise- free pixels remain completely independent of the pixel values of the noisy pixels.

Algorithm

STEP 1: Convert the video into individual frames.

STEP 2: Perform border replication on the given noisy image.

STEP 3: Consider a 3x3 window for filtering consisting of unity elements.

STEP 4: Place the window in such a manner that the central element of the window is over a noise free pixel.

STEP 5: Once the window is placed, multiply the elements of the window with the corresponding overlapped pixel of the image and store it in an array, say S. If the element is over a noisy pixel, it has to be omitted from the process.

STEP 6: Compute the number of noise-free pixels overlapped by the pixel, say N.

STEP 7: Replace the central element by the median value of S.

STEP 8: Repeat steps 3 to 6 until the entire image is traversed.

Result and Analysis

In the paper, several experiments are carried out to analyse the performance of the proposed scheme. Our approach successfully suppressed the salt and pepper noise, better than the existing techniques. This scheme is able to preserve the fine details of the image as well. To validate the results of the proposed method various parameters such as MSE, PSNR and SMSE were compared for various denoising techniques such as mean filtering, adaptive filtering technique and the proposed method. To identify how well the proposed filtering technique works for different values of noise density, ‘xylophone’ video was taken and to each frame, salt and pepper noise was added in such a fashion that the noise density increases linearly with the frame number.

Mean Square Error (MSE)

This criterion studies the amount of difference between the filtered image q_i and the original image p_i. N And M are numbers of rows and columns of the image, respectively.

$$\text{MSE} = \frac{1}{MN}\sum_{i=1}^{N}(p_i - q_i)^2$$

Fig 1 show the simulation results, in terms of MSE measure, for the corrupted video filtered with proposed engine and existing schemes such as Standard Median filter, and Adaptive noise free filter. The proposed scheme provides the lowest mean MSE value for the noisy video. However, SMF and ANF filter schemes have given considerably high values for mean square error.

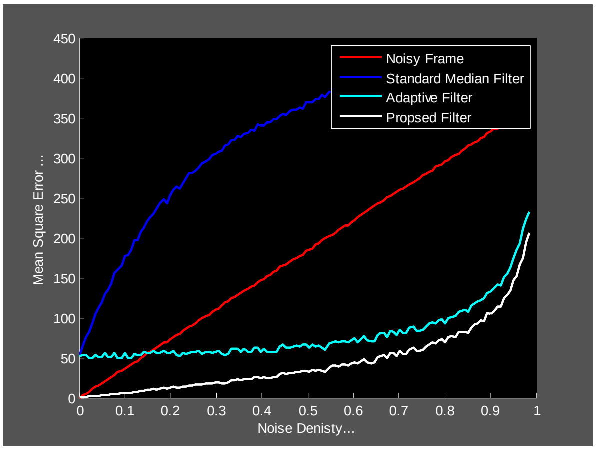

Figure 1: Mean Square Error

Peak Signal-to-noise Ratio (PSNR)

PSNR is a fidelity measurement of an image representation. It measures the ratio of maximum signal power to the ratio to the power of the corrupting noise. Due to the wide dynamic range of signals, PSNR is usually represented in the logarithmic decibel scale.

PSNR is given by the relation

$$\mathrm{PSNR} = 20\log\left[\frac{2^n - 1}{\sqrt{MSE}}\right]$$

where 'n' in the BPP value. It should be ideally a high value.

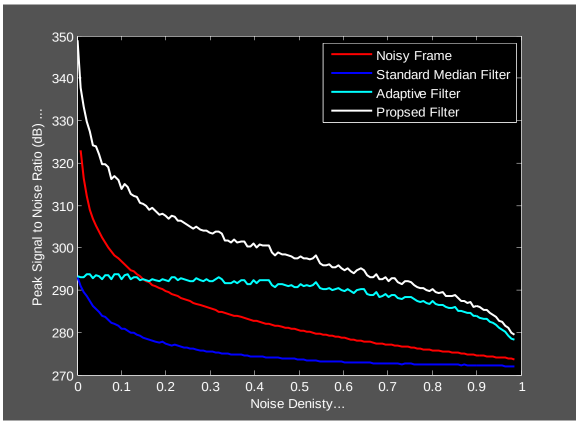

Figure 2: Peak Signal-to-Noise Ratio

Signals to MSE (SMSE)

Since the rate of signal-to-noise is not adequate for evaluating noise in the images, a more proper criterion called SMSE is rather used.

SMSE is given by the relation

$$\text{SMSE} = 10\log_{10}\left[\frac{\sum_{i=1}^{N} p_i^{\,2}}{\sum_{i=1}^{N}(p_i - q_i)^2}\right]$$

Where, p_i is the original image and q_i is the filtered output. It should be ideally a high value. It is clear from Fig 2 that the proposed scheme has better PSNR value.

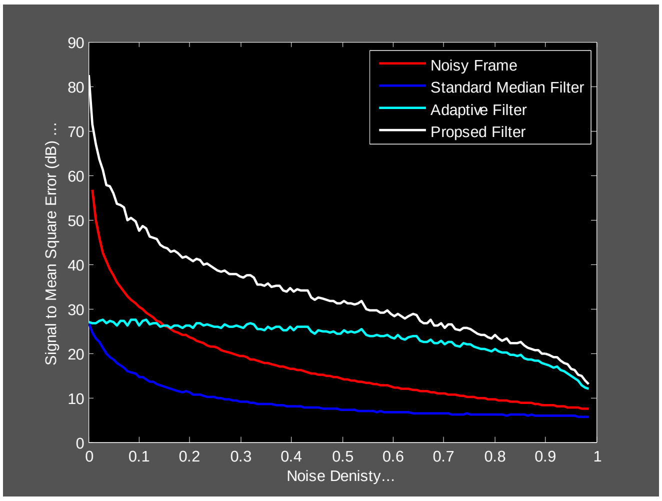

Figure 3: Signal to MSE

Fig 3 show the simulation results, in terms of SMSE measure, for the corrupted video filtered with proposed engine and existing schemes such as Standard Median filter, and Adaptive noise free filter. The proposed scheme provides the highest mean SMSE value for the noisy video. However, SMF and ANF filter schemes have given considerably low values.

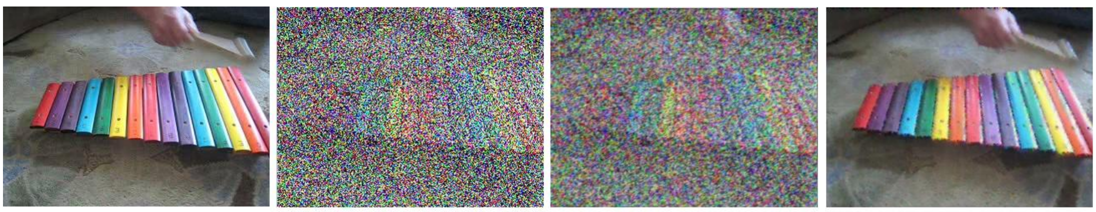

Figure 8: (a) Original frame (b) Noisy frame (c) Denoised using Median Filter (d) denoised using the proposed method

Table 1: Comparison of parameters

Parameter	SMF	AMF	Propsed
MSE	331.557	79.778	45.814
PSNR	275.3dB	289.6dB	299.6dB
SMSE	9.03dB	23.37dB	33.31dB

Conclusion

Images taken with both digital cameras and conventional film cameras will pick up noise from a variety of sources. If the numbers of noisy pixels are greater than noise-free pixels then noise filtering become crucial. In the paper, a video processing engine for de-nosing videos corrupted with salt and pepper noise by a noise-free pixel based scheme that iteratively replaces the noisy pixels with the average estimated value from the noise-free pixel set was explained. The performance is evaluated in terms of Mean Square Error (MSE), Peak Signal to Noise Ratio (PSNR) and Signal to MSE (SMSE) and the engine provides superior performance as compared to the existing approaches. However, the execution time required for de-noising videos is quite high; i.e., 46.8 seconds on an average per frame. But this execution time depends entirely on the amount of noise in the frame, if the noise density is low, then the execution time will also be low and vice versa. Moreover, the execution time can be reduced considerably when implemented on an image/video processing optimized digital signal processor.

Unlike the existing techniques, the proposed VPE has negligible effect on the fine details and edges of the image. Thus this can be used for denoising videos where we need to conserve the edges such as echocardiogram.

References

[1] Majid A and Tariq Muhmud, “A novel Technique for the removal of high density impulse noise from digital images”, 2010 ICET 6th international conference., pages 139 to 143.

[2] T. Huang, G. Yang, and G. Tang, "A fast two-dimensional median filtering algorithm”, IEEE Transactions on Acoustics, Speech and Signal processing, vol. 27, pp. 13-18, 1979.

[3] X. Zhengya, W. Hong Ren, Q. Bin, and Y. Xinghuo, "Geometric Features-Based Filtering for Suppression of Impulse Noise in Color Images,” IEEE Transactions on Image Processing, vol. 18, pp. 1742-1759, 2009.

[4] S.-S. Wang and C.-H. Wu, "A new impulse detection and filtering method for removal of wide range impulse noises," Pattern Recognition, vol. 42, pp. 2194-2202, 2009.

[5] Z. Xuming, and X. Youlun, "Impulse Noise Removal Using Directional Difference Based Noise Detector and Adaptive Weighted Mean Filter" IEEE Signal Processing Letters, vol. 16, pp. 295-298, 2009.